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CHAP.

Book VIII.

OF VEGETABLES.

Chap. I.

STRUCTURE OF VEGETABLES.

General Obſervations on organized Bodies.—Conſtituent Principles of Vegetable Matter.—Structure of Plants.—The Stem.—The Bark.—The Wood.—The Pith.—The vaſcular Syſtem in Plants.—Reſpiration of Plants.—The Root.—The Leaves.—The Flower.—The Fruit.—The Seed.—Bonnet's Experiments.—Perpendicular Growth of Plants.—Plants propagated by Slips, Suckers, and Off-ſets.

A DISTINCTION has been eſtabliſhed by philoſophers, which is not deſtitute of utility, though it muſt be confeſſed that in this, as in every other inſtance which regards the ſyſtem of nature, the line of demarcation is ſcarcely defined with ſufficient preciſion.—All natural bodies have been claſſed under two grand diviſions; unorganized and organized bodies. If the phraſe *vegetable life* might be freely admitted, it would be conſiſtent with correctneſs to term the former the inanimate, and the latter the animated parts of creation. Through the former of theſe regions we have already travelled with ſome diligence, though it is to be apprehended not without pain and difficulty to the reader: for an author is but ſeldom an adequate judge of the degree of entertainment which his labours are capable of affording to others.—The latter, which includes what the old writers denominate

the vegetable and animal kingdoms, remains to be confidered.

Unorganized bodies, we have feen, confift of fimple combinations of many different elementary principles. Organized bodies, on the contrary, confift of few principles; but in the proportions, combinations, and arrangement of thefe principles, they are infinitely varied; and their ftructure is as complex, as their materials are fimple. Thus, in the mineral creation we may enumerate not fewer than forty diftinct elementary principles; the vegetable creation for the moft part confifts only of three; and the utmoft to which it can be extended, is about fix or feven diftinct fpecies of matter, which occafionally enter into the compofition of thofe varied beauties, that fingularity of ftructure, that vaft affemblage of organized bodies, fo different in qualities and external appearance, which the woods, the fields, and the gardens, prefent to our view: fo numerous that they have hitherto eluded the art of the moft fkilful botanift to methodize and arrange.

The conftituent or elementary principles of vegetables, are hydrogen, oxygen, and charcoal. Thefe, as far as our obfervations have hitherto extended, are common to all vegetables. There are fome other fubftances, fuch as calcarious earth, iron, and azote, which are occafionally found in vegetables; but as they are not common to all plants, they cannot be confidered as effential to the conftitution of vegetable matter.

But if the materials of which vegetables are compofed are fo few and fimple, their organization is curious beyond any thing which the mineral world prefents to our view. The parts of vegetables, which naturalifts are accuftomed to confider as diftinct in their nature and functions, are fix, the ftem or trunk, the

root,

root, the leaf, the flower, the fruit, and the ſeed. In many vegetables the root appears nearly ſimilar, in all its conſtituent parts and principles, to the ſtem or trunk, and indeed the one ſeems a continuation of the other; which muſt be my apology for reverſing in ſome degree the order of nature, and treating firſt of that part, which though it ſeems to proceed or ſpring immediately from the other, is yet the moſt perfect in its organization, and is in general of the greateſt uſe and importance to man.

I. The ſtem or trunk, which includes alſo the branches, I might ſay all the more ſolid and ſubſtantial parts of a tree or plant, conſiſts of three parts, the bark, the wood, and the pith.

1ſt. The bark is protected on the outſide, by a cuticle, epidermis, or ſcarf-ſkin, which conſiſts ſometimes of numerous layers, and differs in thickneſs in different plants. This ſkin or cuticle is an organized body, compoſed of very minute bladders, often interſperſed with longitudinal woody fibres, as in the nettle, thiſtle, and the generality of herbs. It contains alſo longitudinal veſſels, and is viſibly porous in ſome plants, and particularly the cane.

On removing the cuticle, the true bark appears, and may be conſidered as a congeries of pulp or cellular ſubſtance, in which are placed a number of veſſels, as well as longitudinal fibres. The veſſels of the bark are differently ſituated, and deſtined for various uſes, in different plants. In the bark of the pine, for inſtance, the inmoſt are lymph-ducts, exceedingly minute; thoſe neareſt the ſurface are gum or reſiniferous veſſels, for the ſecretion of the turpentine, and theſe are ſo large as to be viſible to the naked eye.

2d. The wood lies between the bark and the pith. Its ſubſtance is denſer than that of the bark, and its

ſtructure more difficult to be underſtood. It is however generally ſuppoſed to conſiſt of two ſubſtances, the parenchymatous or cellular, and the ligneous. The ligneous parts are no more than a congeries of old, dried lymp-ducts. Between the bark and the wood a new ring of theſe ducts is formed every year, which gradually loſes its ſoftneſs as the cold ſeaſon approaches, and towards the middle of winter is condenſed into a ſolid ring of wood. Theſe annual rings, which are viſible in moſt trees when cut tranſverſely, ſerve as marks to determine their age. They ſeem to decreaſe in breadth, as the tree advances in age; and as they are found to be very unequal in ſize throughout, their breadth probably varies according as the ſeaſon is favourable or otherwiſe.

The wood differs from the bark, not merely in the degree of hardneſs; its ſtructure is eſſentially different, and the apparent converſion of bark into wood is entirely a deception. One ſtriking difference between the wood and the bark is, that the former is poſſeſſed of ſpiral veſſels which run from one end of the tree to the other. From the great reſemblance of theſe air-veſſels to thoſe of inſects, they are ſuppoſed to be ſubſervient to the ſame function. The ſtem of ſome plants is entirely hollow, partly, it is ſuppoſed, from theſe plants, which are generally of a quick growth, requiring a more than ordinary ſupply of air.

3d. The pith is ſituated in the center of the ſtem, and in young plants it is very abundant. It is ſaid by ſome authors to conſiſt of exactly the ſame ſubſtance as the parenchyma or cellular ſubſtance of the bark; and to be compoſed of ſmall cells or bladders, generally of a circular figure, though in ſome plants, as the borage and thiſtle, they are angular. In moſt plants the pith

 gra-

gradually dies away as they approach to maturity; and in old trees it is almoſt entirely obliterated.

Such are the ſolid parts of plants; but to render their organization more clearly underſtood, in plate I. fig. 1. is the ſection of a branch of aſh, cut tranſverſely as it appears to the eye. Fig. 2. is the ſame ſection magnified. A. A. the bark. B. B. B. an arched ring of ſap-veſſels next the cuticle. C.C.C. the cellular ſubſtance of the bark, with another arched row of ſap-veſſels. D. D. a circular line of lymph-ducts next the wood. E. E. the wood. F. the firſt year's growth. G. the ſecond. H. the third. I. I. I. the true wood. K. K. the great air-veſſels. L. L. the leſſer air-veſſels. M. M. M. parenchymatous inſertions of the bark, repreſented by white rays. N. O. the pith.

The name of air-veſſels, as was before remarked, has been given to certain tubes ſituated in the wood, leaves, and petals, but not in the bark of trees. They are formed by a number of ſmall filaments, ſpirally rolled up ſo as to form a cavity in the middle, and are ſuppoſed to be the inſtruments of reſpiration in plants; but how this function is performed, is not clearly underſtood. Trees and ſhrubs only are poſſeſſed of air-veſſels; and when a plant is placed under the exhauſted receiver of an air-pump, the air only iſſues from the wood, in which the air-veſſels are ſituated.

There is reaſon to believe that the air's proper entrance to plants is through the cuticle, which is proved to be a vaſcular ſubſtance, ſince, when under an exhauſted receiver, it iſſues directly through the cuticle. That the air is neceſſary to the ſuſtenance of plants, appears from the experiments of Dr. Bell *. In the

* See his excellent Theſis on the Phyſiology of Plants, Manch. Mem. vol. ii.

winter ſeaſon he covered ſeveral young trees with varniſh, leaving the tops of the branches only expoſed to the air. They remained in this ſituation during the following ſummer, when ſome of them lived, though in a languid ſtate; but thoſe from which the air had been more accurately excluded, died without a ſingle exception. To this proof the ſame author adds, that trees overgrown with moſs have few leaves, weak ſhoots, and ſcarcely any fruit; and that it is the common practice of all judicious gardeners to ſtrip the moſs from the bark of aged trees, which by admitting the air, generally reſtores them to vigour and fruitfulneſs.

II. The root, which fixes the plant to the earth, and is the chief ſource of its nouriſhment, differs much in different ſpecies of vegetables. All roots agree in being fibrous at their extremities, and it is by their fibres chiefly that they are fitted to draw nouriſhment. The root terminates upwards in the ſtem or trunk, which ſuſtains the other parts of the vegetable. The internal ſtructure of the root, or rather of its fibres, differs not very materially in general from that of the ſtem. It conſiſts of a cuticle, bark, wood, and commonly of a ſmall portion of pith; though there are ſome roots which have no pith at all, while there are others which have little or none at the extremities, but a conſiderable quantity near the top. The cuticle, in all roots at a certain age, is double; the cortical ſubſtance, or bark, differs greatly in its quantity and diſpoſition in different plants. In trees it is thin; in carrots, on the contrary, it is one half of the ſemidiameter of the root; and in dandelion it is nearly twice as thick as the woody part. The roots, as well as the trunk of plants, are furniſhed with a variety of

veſſels

veſſels for the purpoſe of conveying and circulating air and the juices neceſſary to their nouriſhment.

In plate I. fig. 3. is a ſection of the root of wormwood, as it appears to the eye; and fig. 4. is the ſame magnified. A. A. the ſkin with its veſſels. B. B. B. the bark. C. C. C. the lymph-ducts of the bark. The other holes are ſmall cells or ſap-veſſels. D. D. D. parenchymatous inſertions from the bark. E. E. E. the rays of the wood, with the air-veſſels.—This root has no pith.

III. The leaves are organs eſſential to the exiſtence of plants. Trees periſh when totally diveſted of them; and in general, when ſtript of any conſiderable proportion of their leaves, they do not ſhoot vigorouſly. The leaves are formed by the expanſion of the veſſels of the ſtalk into a net-work, which exhibits a beautiful appearance when the intermediate parenchymatous matter is conſumed by putrefaction. Both ſurfaces of the leaf are covered with a membrane, which is a thin bark, continued from the ſcarf-ſkin of the ſtalk.

IV. The flower conſiſts of four parts, the calyx, the corolla, the ſtamina, and the piſtilium. The calyx or flower-cup is almoſt always of a green colour, and is that which ſurrounds and ſupports all the other parts of the flower. The corolla is of various colours, is variouſly ſhaped in different vegetables, and is that which conſtitutes the moſt conſpicuous part of the flower. It ſometimes conſiſts of one continued ſubſtance, but more frequently of ſeveral portions, which are called petals. The ſtamina are ſuppoſed to be the male part of the flower. Linnæus defines them to be an entrail of the plant, deſigned for the preparation of the pollen. Each ſtamen conſiſts of two parts; the filimentum or fine thread which ſupports the anthera, and the anthera or head

itſelf, which contains within it the pollen, and when come to maturity diſcharges it for the impregnation of the germen. From the ſuppoſed function of the ſtamina, they afford the chief foundation of the diſtribution of the vegetable ſyſtem into claſſes. Such flowers as want this part are called female; ſuch as have it, but want the piſtillum, male; ſuch as have them both, hermaphrodite; and ſuch as have neither, neuter.

The piſtillum or pointal is ſuppoſed to be the female part of the flower; it is defined by Linnæus to be an entrail of the plant, deſigned for the reception of the pollen. It conſiſts of three parts, the germen, the ſtyle, and the ſtigma. The germen is the rudiment of the fruit accompanying the flower, but not yet arrived at maturity. The ſtyle is the part which ſerves to elevate the ſtigma from the germen. The ſtigma is the ſummit of the piſtillum, and is covered with a moiſture for the breaking of the pollen.

The pericarpium or ſeed-veſſel is the germen grown to maturity. Such are the conſtituent parts of the flower; they are however infinitely varied, and ſerve both to diverſify the face of nature, and to intereſt and delight the curioſity of man. One curious fact it is neceſſary to notice before I diſmiſs this branch of my ſubject, and that is, that every flower is perfectly formed many months before it makes its appearance. Thus the flowers which appear in this year are not properly the productions of this year: the mezereon flowers in January, but the flowers were completely formed in the bud in the preceding autumn. If the coats of the tulip-root alſo are carefully ſeparated about the beginning of September, the naſcent flower, which is to appear in the following ſpring, will be found in a ſmall cell, formed by the innermoſt

coats,

Fig. 2.

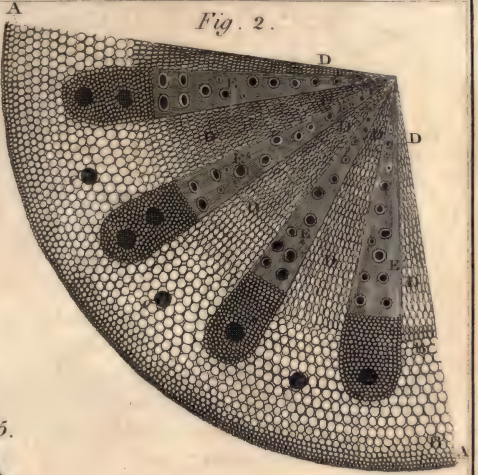
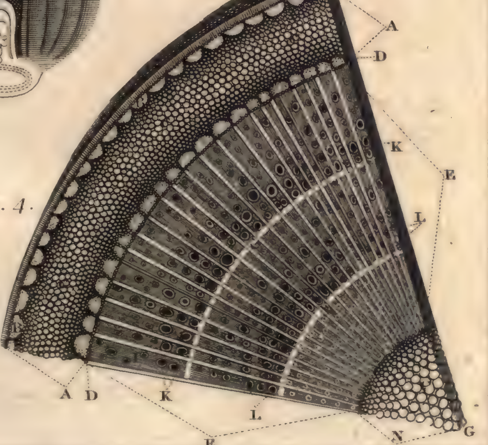


Fig. 1.

Fig. 5.

Fig. 3.

Fig. 4.



coats, as reprefented in plate I. fig. 5. where the young flower appears towards the bottom of the root.

V. The fruit confifts of nearly the fame parts as are found in the ftem; of a fkin or cuticle, which is a production or continuation of the fkin of the bark; of an outer parenchyma, which is the fame fubftance continued from the bark, only that its veficles are larger and more fucculent or juicy. Next the core there is commonly an inner pulp or parenchyma; and the core is no more than a hard woody membrane, which inclofes the feed. It is to be obferved, however, that the organization of fruit is very various; in fome the feeds are difperfed through the parenchymatous or pulpy fubftance; in fome, inftead of a core, we find a ftrong woody fubftance inclofing the feed or kernel, which from its great hardnefs is termed the ftone; in fome, there are a number of feeds; and in others, only a fingle feed, inclofed in a large mafs of parenchymatous matter.

VI. The feed is a deciduous part of a vegetable, containing the rudiment of a new one. The effence of the feed confifts in the corculum or little heart, which is faftened to the cotyledones or lobes, and involved in them, and clofely covered by its proper tunic. The corculum confifts in the plumula, which is the vital fpeck of the future plant, extremely fmall in its dimenfions, but increafing like a bud to infinity. The roftellum, however, muft be included, which is the bafe of the plumula; it defcends and ftrikes root, and is the part of the feed originally contiguous to the mother plant. It is commonly fuppofed, and with fome reafon, that the perfect plant, or at leaft all the organization which is requifite to a perfect plant, exifts in the feed, furrounded by a quantity of farina-

ceous

ceous matter, which ferves to abforb moifture, and to furnifh nourifhment to the corculum till its parts are fufficiently unfolded to draw fupport from the foil. A kidney-bean or lupine, when it has been foaked for fome time in water, and begun to fwell, is eafily feparated into its two lobes; and between thefe is difplayed the nafcent plant. The naked eye can eafily difcern the ftem, and its connexion with the lobes. Through the lobes are diffufed innumerable veffels, which immediately communicate with the embryo plant. On the external furface of the feed are abforbent veffels, which attract the moifture; by this moifture a degree of fermentation is produced, and thus a juice is prepared by a natural procefs in every refpect proper for the nourifhment of the plant in its firft efforts to extend its tender frame. The plant in its infancy is almoft a gelatinous fubftance, and increafes and indurates by degrees; and I believe in general the hardnefs of wood bears a pretty exact proportion to the flownefs with which a plant increafes. That part of the ftem which is next the root is the firft which affumes the woody texture.

M. Bonnet, in order to afcertain how far the lobes of the feed were neceffary to the growth and health of the corculum, detached them with great dexterity without a vital injury to the infant plant. Some French-beans treated in this manner, and fowed in a light foil, grew, but the confequence was, that not only the firft leaves were much fmaller, but the plants were uniformly weaker in every part of their growth than others, which for the fake of comparifon were fown at the fame time without being mutilated. The feeds which were deprived of the lobes put forth fewer bloffoms, and produced lefs feed. The feeds of moffes are naturally devoid of lobes. The firft leaves which

which make their appearance, and which are called ſeminal, appear not leſs neceſſary to the perfection of the plant than the farinaceous lobes. If they happen to be broken off, the plant experiences a proportional loſs of vigour.

It is a matter of curious obſervation, that ſeed, thrown into the ground at random, ſhould always come up in the proper direction. M. Dodart has offered an ingenious explanation of this fact, which conſiſts in ſuppoſing that the roſtellum contracts by humidity, and that the plumula on the contrary contracts by dryneſs. According to this idea, when a ſeed is put into the ground the wrong way, the roſtellum, which then points upwards, contracts itſelf towards the part where there is moſt humidity, and therefore turns downwards. The plumula on the contrary pointing downwards, turns itſelf towards the part of the ſoil which is drieſt, and therefore riſes towards the ſurface. This explanation, however, evidently reſts on no better baſis than conjecture.

Independent of the ſeed, there are two other methods by which plants are propagated, by ſlips and ſuckers; and many plants naturally make an effort to propagate themſelves in this manner. The bulbous-rooted plants in general increaſe by off-ſets. When a tulip is firſt planted in the ſpring, the ſtem iſſues from the middle of the bulbous root; but when the tulip is taken up in the autumn, the ſtem no longer proceeds from the middle of the root, but ſeems attached to one ſide. The fact is, that the root which is taken up is not the ſame that was planted. The original root has decayed by having its ſubſtance abſorbed for the nouriſhment of the bloſſom, and a new root has been provided for the future year.

Chap. II.

FLUIDS OF VEGETABLES.

The Succus Communis or Sap.—Vessels for the Circulation of the Sap.—Succus Proprius; its Vessels and Course.—Bonnet's Experiments on the Nourishment of Plants.—Dr. Hale's Experiments on Fruit Trees.—Bonnet's on Flowers, &c.

THE fluids or juices of vegetables, says Dr. Bell, are of two kinds. 'The one is of the same nature in all the variety of vegetables: the other varies according to the different plants in which it exists. The former, which is called the *succus communis*, when collected early in the spring, from an incision made in the birch or vine, differs little from common water *. The latter, which is named the *succus proprius*, possesses various properties in various plants, and gives to each its sensible qualities. These two juices never mingle with each other in the tree, and the latter is found in the *vasa propria* only.

'It is not yet ascertained, whether the juices of plants are transmitted through vessels, or cellular substance. Each side of the question has had its advocates, who have supported their respective opinions with probable arguments: but it is to be regretted, that,

* It has, however, been alledged to contain a saccharine matter in some trees, as in the sugar maple, &c. It has likewise been supposed to contain an acid. But, in various experiments which Dr. *Bell* made on it, he found nothing in it of either kind; and therefore, where such appearances have taken place, he supposed them to arise from an adventitious mixture of the sap, and the *succus proprius*.

that, on so interesting a subject, no conclusion can be formed from the actual dissection of vegetables. It however seems most probable, that all the fluids of plants are transmitted through vessels, for the following reasons. 1. The existence of *vasa propria* and *vasa aëria* is discoverable by the naked eye, and made still more manifest by the microscope. That *succus proprius* and air are contained in these is evident, and therefore analogy leads us to believe, that the *succus communis* is also contained in vessels. 2. Secretion, of which vegetables have undoubtedly the power, is in no instance, that we know of, performed without the action of vessels. 3. An experiment, made by Dr. Hales, seems clearly to prove, that the sap is contained within its own vessels, and does not fortuitously pervade every interstice of the plant. He fixed an instrument round the stem of a vine, by which its contractions and expansions could be accurately measured; but he found no difference in the circumference of the trunk, when the tree was full of sap, and when it was entirely without it, although the instrument employed was so nice, as to detect a variation of the hundredth part of a finger's breadth. If the sap had been transmitted, without vessels, through the cellular substance, this, on the withdrawing of the sap, would have been compressed, and of course the stem of the tree would have contracted itself into a smaller compass *.

* To determine this question absolutely, it may seem, that the most certain and obvious method would be by injections, the great source of our knowledge of the anatomy of animals. They have been employed by Bonnet, Dr. Hope, and others, but they have failed. They rise a considerable way into plants, but as, in different cases, they take different courses, from this and other circumstances there is reason to believe, that their course, and that of the sap, are materially different from each other.

' Botanists

'Botanifts have made many experiments to afcertain the courfe of the fap. Early in the fpring, when the fap begins to flow, incifions have been made in the trunk and branches of trees, as far as the pith; and, in fuch cafes, it has been conftantly found, that a larger quantity of fap flowed from the fuperior, than from the inferior margin of the incifion. This circumftance led to the opinion, that in the beginning of the fpring, great quantities of moifture are abforbed by trees from the atmofphere, and hence the fource of the abundance of fap *. But this conclufion is found to difagree with the phenomena of nature, from the two following experiments.

'1. Incifions of various heights being made in the ftem of feveral plants, their roots were immerfed in a decoction of log-wood. The roots abforbed the coloured liquor, which at length began to flow from the fuperior, and not from the inferior, margins of the incifions; nor had the liquor extended itfelf much upwards, beyond the margin of the incifion from which it was difcharged.

'2. In the feafon when the fap flows moft abundantly, called the bleeding feafon, a deep cut was made into the branch of a growing vine, and the greateft quantity of fap was difcharged from the upper margin of the incifion: but a branch of the fame tree, cut in the fame manner, being inverted, the fap flowed moft copioufly from the other margin of the incifion, which of courfe was now that next the root. On the other hand, many experiments may be brought to prove directly, that, in the bleeding feafon, the fap afcends from the roots towards the branches; the following however may fuffice. 1. Early

* Du Hamel and others.—See Phyf. des Arbres, Tom. I. p. 67.

in the ſpring, when little or no ſap had as yet entered the plant, Dr. Hope made a number of inciſions of different altitudes, into the root and ſtem of a birch. As the ſap roſe, it firſt flowed from the ſuperior margin of the loweſt inciſion, and then, in regular ſucceſſion, from the upper margins of the other inciſions, till at laſt it reached the higheſt. 2. If, in the beginning of the bleeding ſeaſon, before the ſap is found in the ſtem or branches, an inciſion is made in the root of a vine, a conſiderable flow of ſap will follow the wound, 3. The quantity of ſap is very generally proportioned to the humidity of the ſoil *.

' When a portion of the bark and wood of the pine is cut from the ſtem, the *ſuccus proprius* flows in conſiderable quantity both from the upper and under margin of the inciſion. Hence it occurred to botaniſts, that this juice might have little or no motion, and that its efflux from ſuch an orifice might depend entirely on its being freed from the preſſure of the bark and wood. But I cannot accede to this opinion: for although, in the beginning, the *ſuccus proprius* flows from both margins of the inciſion, in a little while, as I have obſerved, it is diſcharged from the ſuperior

* It may ſtill be aſked, Why the ſap flows moſt from the ſuperior margin of each inciſion, ſuppoſing it to ariſe from the roots? The inciſion, it is ſaid, hurts or deſtroys the energy of the ſap-veſſels for a conſiderable way below, whence the ſap is not propelled upwards againſt its own weight, and the preſſure of the atmoſphere now admitted. From the divided veſſels, it paſſes by a lateral communication (for there are ſap-veſſels in every direction) into thoſe undivided, and when it has got above the inciſion, it again paſſes laterally into the divided veſſels; and falling downwards, from its own gravity, a want of continuity of veſſels, and the diminiſhed preſſure of the atmoſphere, it flows from the ſuperior margin of the inciſion.

margin

margin only. This obſervation in itſelf is not however deciſive. For it may be ſuppoſed, that the liquor flows more copiouſly from the ſuperior margin, becauſe the preſſure of the air is leſs upon it, than on the inferior, and becauſe the liquor itſelf is diſpoſed to fall downwards by its gravity, in the ſame manner as the *ſuccus communis*. That I might put this matter out of doubt, I placed the branch of a pine in a horizontal poſition, and another branch I inverted, ſo that its branches were turned towards the earth. In theſe ſituations, I cut a portion of the bark and wood from each, and in both inſtances, the *ſuccus proprius* flowed only from thoſe margins of the inciſions which were fartheſt from the roots. Hence it appears clearly, that the courſe of this juice, in its veſſels, is never from the roots towards the branches, but always in the contrary direction *.'

M. Bonnet conceives that the nutrimental juices of vegetables paſs during the day-time from the roots to the trunk by the ligneous fibres, aſſiſted by the air-veſſels, and are principally carried to the ſurface of the leaves, where a copious perſpiration takes place. At the approach of night the heat no longer acting on the leaves and the air contained in the air-veſſels, the ſap returns towards the roots; at the ſame time that the humidity condenſed on the inferior ſurfaces of the leaves, which by their inequalities are beſt fitted to retain it, is abſorbed and conveyed through the branches to the trunk. In this manner he is of opi-

* From the experiment above recited, it appears, that the flow of the proper juice is not influenced in the ſame degree, as that of the ſap, by an alteration in the poſture of the veſſels from which it iſſues. To what cauſe this is owing, does not clearly appear.

nion

nion that vegetables are nouriſhed in the day-time by their roots, and in the night by their leaves.

The ſame philoſopher wiſhed to diſcover whether plants nouriſhed by their leaves would live as long, and thrive as well, as others nouriſhed by their roots. He plunged in ſmall veſſels, filled with water, plants of mercury, immerſing the leaves of ſome and the roots of others. He left to each plant one or two ſprigs, which were kept out of the water, and which were only nouriſhed by the part of the plant which was immerſed. He rendered all theſe ſprigs as equal and as much alike as poſſible. He left the plants in this ſituation for five or ſix weeks, at the end of which time he could obſerve no difference between the ſprigs uniformly nouriſhed by the leaves, and thoſe nouriſhed by the roots. He only remarked that the leaves plunged in water ſeemed to ſuffer a little more from the action of that fluid than the roots. M. Bonnet alſo buried the top of a willow-tree, leaving the roots above ground. The roots being prevented from drying by a covering which did not entirely exclude the air, put forth leaves mixed with roots; the top, which was buried in the ground, produced roots, and the plant continued to live.

Dr. Hales, in his ſtatical experiments, mentions ſeveral in which he tried to change the natural flavour of fruits, and to communicate thoſe of ſeveral ſpirituous liquors, and of different odoriferous infuſions. With this intention he plunged in different liquors branches loaded with fruit; and left them there for ſome time, without being able to perceive that the taſte of the fruits was in the leaſt altered, whether the experiment was made upon them ripe or unripe. But he almoſt always perceived the ſmell of the liquors or infuſions in the ſtalks of the leaves, and in the wood. He

conjectures, with much probability, that the veſſels near the fruit become ſo fine as not to admit the odoriferous particles.

M. Bonnet made experiments on flowers ſimilar to thoſe which Dr. Hales made on fruits. He choſe ſuch flowers as have naturally little perfume, as the different ſpecies of French-beans. Stems with theſe flowers were immerſed in tubes, ſome of which were filled with ſpirits of wine, others with Hungary water, &c. In about twenty-four hours the flowers were faded, and they had already acquired in a very ſenſible degree the odours of the liquors which they had imbibed. The odour became much more remarkable a few days afterwards. M. Bonnet alſo found that the leaves of the apricot-tree acquired a ſenſible odour from the liquors into which branches of that tree were plunged.

CHAP. III.

FUNCTIONS OF VEGETABLES.

Perspiration of Plants.—Circulation of the Fluids in Plants.—Property in Plants of emitting vital Air; of decomposing Water.—Sensibility to the Sun's Light.—Cause of the Green Colour of Vegetables.—Bonnet's Experiments on Vegetable Perspiration.—Sexual System.—Growth and Nutriment of Vegetables.—Manures.—Principles of Agriculture.

THE leaves of plants have been not improperly compared with the lungs of animals. 'Plants as well as animals,' says an author whom I have already quoted with approbation, 'perspire, and in both cases this function is essential to health. By the experiments of Dr. Hales *, and M. Guettard †, it appears, that the perspirable matter of vegetables differs in no respect from pure water, excepting that it becomes rather sooner putrid. The quantity perspired varies, according to the extent of the surface from which it is emitted, the temperature of the air, the time of the day, and the humidity of the atmosphere. As the leaves form the greatest part of the surface, it is natural to suppose, that the quantity of these will very materially affect the quantity of the perspiration. Accordingly, the experiments of Dr. Hales have ascertained, that the perspiration of vegetables is increased or diminished, chiefly, in proportion to the increase or diminution of their foliage ‡. The degree of heat in which the plant was kept, according to the same author,

* Statical Essays, vol. i. p. 49.

† Mem. de l'Academie des Sciences, 1748.

‡ Statical Essays, vol. i. p. 29.

author, varied the quantity of matter perſpired; this being greater, in proportion to the greater heat of the ſurrounding atmoſphere. The degree of light has likewiſe conſiderable influence in this reſpect: for Mr. Philip Miller's experiments prove, that plants uniformly perſpire moſt in the forenoon, though the temperature of the air, in which they are placed, ſhould be unvaried. M. Guettard likewiſe informs us, that a plant, expoſed to the rays of the ſun, has its perſpiration increaſed to a much greater degree, than if it had been expoſed to the ſame heat, under the ſhade. Finally, the perſpiration of vegetables is increaſed in proportion as the atmoſphere is dry, or in other words, diminiſhed in proportion as the atmoſphere is humid.'

Dr. Hales found that a ſun-flower, weighing three pounds, perſpired twenty-two ounces during twenty-four hours. Dr. Keil perſpired thirty-one ounces in twenty-four hours. The quantity therefore perſpired by the ſun-flower was much greater, in proportion to its weight, than that perſpired from the human body. Dr. Keil ate and drank four pounds ten ounces in twenty-four hours. Seventeen times more nouriſhment was taken in by the root of the ſun-flower, than was taken in by the man. If the perſpiration of vegetables is checked, they ſpeedily fade. It is checked from glutinous ſubſtances adhering to their ſurface; hence the advantage of waſhing them. The more healthy and vigorous the plant, the more copious the perſpiration; though an exceſs, as well as a defect of it, ſeems prejudicial and even deſtructive to vegetables. It bears alſo a proportion to the quantity of leaves, theſe being the principal organs of perſpiration.

The odoriferous exhalation of leaves and flowers forms an atmoſphere around vegetables, which ſtrikes our

our ſenſes, and which the contact of a body of fire is ſometimes capable of inflaming, as has been obſerved with regard to the fraxinella.

‘ Some botaniſts,’ obſerves Dr. Bell, ‘ have conceived, that plants, as well as animals, have a regular circulation of their fluids. Others think this very improbable. On both ſides, recourſe has been had to experiments; and from theſe, concluſions perfectly oppoſite have been deduced. When a ligature has been fixed round a tree, in ſuch a manner that no juice could be tranſmitted through the bark, the tree has been found to thicken above the ligature; but below it, to continue of the ſame circumference. Hence ſome have concluded, that the ſap aſcends through the wood, and deſcends through the bark. Thoſe who are of a contrary opinion have found, that, in certain caſes, the juice aſcends through the bark only: for when a portion of the wood has been cut out, and the bark exactly replaced, the growth of the tree has been found to go on unchanged: hence it is ſaid, that the juice is tranſmitted equally through all parts of vegetables. The experiments adduced on each ſide of the queſtion are juſt, but the reaſonings on theſe, by each party, ſeem equally inconcluſive. The analogy of animal nature appears to favour the opinion, that the juice riſes through the wood only, and deſcends only through the bark; but this analogy is not complete throughout. The arteries are not placed in the internal parts alone, nor the veins in the external, but they accompany each other through every part of their diſtribution. In vegetables, the ſap riſes *from* the roots, but the proper juice deſcends *towards* them; in the deſcent of the juice, the wood acquires its growth, and abſorption is a conſtant action of the leaves. Theſe obſervations render it probable, that there is a circulation

of the juices; and if there is, the veſſels which perform it, we may reaſonably believe, accompany each other through every part of their courſe.'

By what force the juices of plants are propelled in their circulation, remains yet one of the ſecrets of nature. It has been attributed to capillary attraction, but this cauſe ſeems inadequate to the effect; nor is it poſſible on that principle to explain why the ſap of the vine flows from an inciſion made in the ſpring, and not from one made in the ſummer. The capillary attraction ought not to be leſs powerful in the latter than in the former ſeaſon; indeed it ought to be more ſo, as the heat is greater. Beſides, capillary tubes do not diſcharge their contents when broken acroſs; but from the ſtem of a plant cut tranſverſely, a large quantity of fluid is diſcharged. The more probable opinion is, that plants are endued with ſomething of a vital power or energy, which impels the juices through the whole vaſcular ſyſtem; and this opinion is ſtrengthened by an obſervation of Dr. Bell, which was the reſult of experiment, namely, that there are particular ſubſtances which increaſe the growth of plants, by acting as ſtimulants on their fibres.

The experiments of Dr. Prieſtley have ſufficiently ſhewn that vegetables have the power of correcting bad air; and Dr. Ingenhouz has proved that they have the faculty of producing vital air only when acted on by the rays of light. If a vegetable is immerſed in water, and the rays of the ſun directed on it, air-bubbles will be obſerved to collect on the leaves, and at length riſe to the ſurface of the water. This appearance is moſt remarkable in the morning, as the leaves have not then been previouſly exhauſted by the action of light. Vital air of a great degree of purity may be obtained in the ſummer time, by inverting a jar

filled with water in ſuch a manner as to receive the air-bubbles as they ariſe. All plants, however, do not emit this air with the ſame facility; there are ſome which emit it the moment the rays of the ſun act upon them, and this is the caſe with lavender. Some aquatic plants afford vital air with great facility, ſome more ſlowly, but none later than in eight or ten minutes, provided the ſun's light is ſtrong. The air is almoſt entirely furniſhed by the inferior ſurface of the leaves of trees; herbaceous plants afford it from almoſt the whole of their ſurface. The leaves afford more air when attached to the plant, than when gathered, and the quantity is greater, the freſher and ſounder they are. Young leaves afford but a ſmall quantity of vital air; thoſe which are full grown afford more, and the more the greener they are. The epidermis, the bark, and petals do not afford it, and in general vital air proceeds only from thoſe parts of plants which are of a green colour. Thus green corn and green fruits afford this air, but it is not produced by thoſe which are ripe; and flowers in general render the air noxious. Theſe facts may tend to explain the manner in which the light of the ſun operates in maturing fruits, viz. by expelling the ſuperfluous oxygen, and thus changing them from a harſh and ſour, into a mild and ſweet ſubſtance. Aquatic plants, and ſuch as grow in moiſt places, are remarkable not only for affording a large quantity of vital air, but alſo for abſorbing inflammable gas, and are therefore in all reſpects calculated for purifying the air of marſhy ſituations. A very extraordinary power of abſorbing inflammable air was obſerved in the willow by Dr. Prieſtley; and this fact ſeems connected with the rapid growth of that plant in marſhy ſituations, where much inflammable air is produced. M. Sennabier

found that plants yield much more vital air in distilled water impregnated with fixed air, than in simple distilled water.

It appears further, from the experiments of Dr. Priestley, that plants will bear a greater proportion of inflammable than of fixed air, and that vital air appeared generally injurious to plants. A sprig of mint growing in water, placed over a fermenting liquor, and of course exposed to fixed air, became quite dead in one day; a red rose became of a purple colour in twenty four hours. Plants die very soon both in nitrous air, and in common air when saturated with it. Air appears uniformly to have been purified by healthy plants vegetating in it; but these experiments require great nicety, as the least degree of putrefaction will injure the air. The air contained in the bladders of marine plants was found considerably purer than common air.

Atmospheric air is restored, after being injured by respiration or combustion, by a plant vegetating in it. This restoration of air depends upon the vegetating state of the plant; for a number of mint-leaves fresh gathered being kept in air in which candles had burnt out, did not restore the air. Any plant will effect this purpose, but those of the quickest growth in the most expeditious manner.

That plants have a property of producing pure air from water is evident from an experiment of Dr. Priestley. The green matter which is to be observed in water is doubtless a vegetable production. Water containing this green matter always afforded vital air in a large quantity, but water which had it not afforded none. It has been frequently observed that vegetables do not thrive in the dark. A receiver was therefore filled with water, and kept till it was in a state of giving air

air copiously; after this it was removed into a dark room, and from that time the production of air entirely ceased. When placed again in the sun, it afforded no air till about ten days after, when it had more green matter, the former plants being probably all dead; and no air could be produced till new ones were formed.

From various experiments it appeared, that different animal and vegetable putrescent substances afforded a very copious pabulum for this green vegetable matter, which produced so freely the vital air; whence the philosophic author of this discovery is led to the following conclusions—'It is impossible,' says he, 'not to observe from these experiments the admirable provision in nature, to prevent or lessen the fatal effects of putrefaction, especially in hot countries, where the rays of the sun are most direct, and the heat most intense. Animal and vegetable substances, by simply putrefying, would necessarily taint great masses of air, and render it unfit for respiration, did not the same substances, putrefying in water, supply a most abundant pabulum for this wonderful vegetable substance, the seeds of which seem to exist throughout the atmosphere. By these means, instead of the atmosphere being corrupted, a large quantity of the purest air is continually thrown into it. By the same means also, stagnant waters are rendered much less offensive and unwholsome than they would otherwise be. That froth which we observe on the surface of such waters, and which is apt to excite disgust, generally consists of the purest vital air, supplied by aquatic plants. When the sun shines, this air may be observed to issue from them. Even when animal and vegetable substances putrefy in air, as they have generally some moisture in them, various other vegetable productions, in the form of

mold,

mold, &c. find a proper nutriment in them, and by converting a conſiderable part of the noxious effluvia into their own ſubſtance, arreſt it in its progreſs to corrupt the atmoſphere.'

The ſame vegetables which afford vital air very plentifully in the light of the ſun, afford in the ſhade air leſs pure than that of the atmoſphere. This ſtriking effect of light on vegetables is a ſtrong argument in favour of the opinion, that the motion of the juices of the vegetables is performed by veſſels, which, like thoſe of animals, poſſeſs irritability, and are excited to action by ſtimulating ſubſtances.

The effect of vegetation in producing the vital air, which was afforded in the preceding experiments, ſeemed in ſome meaſure dubious to Sir Benjamin Thompſon, who extracted vital air, by immerſing in water a variety of ſubſtances, as raw ſilk, cotton, wool, eider down, hare's fur, ſheep's wool, ravellings of linen, and human hair—as related in a former book. He was led, from the reſult of theſe trials, to ſuſpect that the pure air was merely ſeparated from the water, and that any ſubſtance which would act by a capillary attraction, ſo as to ſeparate the component parts of the water, would effect the production of pure air. He therefore procured a quantity of ſpun glaſs, which conſiſts of minute tubes, which he immerſed in water, but the quantity of pure air produced was very trifling. Hence he concludes, that there is ſomething in thoſe ſubſtances which operates in producing pure air, and that it is not merely a mechanical ſeparation of the component parts of water.

The light of lamps produced the ſame effect as the ſun's light, air in great quantities was produced, and perfectly pure. Vegetables will alſo, with any ſtrong light, produce vital air as well as with the light of the

ſun.

ſun. The air from ſilk was much ſuperior to that from vegetables.

Plants have a remarkable ſenſibility to light; they unfold their flowers to the ſun, they follow his courſe by turning on their ſtems, and are cloſed as ſoon as he diſappears. Vegetables placed in rooms where they receive light only in one direction always extend themſelves that way. If they receive light in two directions, they direct their courſe towards the ſtrongeſt. Trees growing in thick foreſts, where they only receive light from above, direct their ſhoots almoſt invariably upwards, and therefore become much taller and leſs ſpreading than ſuch as ſtand ſingle. This affection for light ſeems to explain the upright growth of vegetables, a curious phenomenon, too common to be much attended to. It has been aſcertained by repeated experiments, that the green colour of plants is entirely owing to light; for plants reared in the dark are well known to be perfectly white.

If we take a ſucculent plant, and expreſs its juice, the liquor appears at firſt uniformly green; but allow it to ſtand, and the green colour ſeparates from the watery fluid, and falls to the bottom in a ſediment. If we collect this ſediment it will be found to be of an oily nature, for it does not diſſolve in water, but it will in ſpirits of wine, or oil, to which it imparts a green colour. As the ſun produces the green colour in plants, and as this reſides in an oily matter, it was formerly concluded that light furniſhes the oily matter of vegetables, and that it effects this by furniſhing the principle of inflammability. The new chemical doctrines, however, afford a much more ſatisfactory explanation of the effect of the ſun's rays in producing the oily matter in vegetables. Vegetable matter conſiſts in general of carbon, hydrogen and oxygen; the ſun's rays

produce

produce a diſengagement of the latter principle in the form of vital air, and the two former are the conſtituent principles of oil.

M. Bonnet made a ſeries of experiments in order to aſcertain whether the ſuperior or the inferior ſurfaces of leaves have a greater ſhare in performing perſpiration. From the trials which he made, he concludes that the inferior ſurface of the leaf is in general by far the moſt active in this reſpect, though in one or two ſpecies of vegetables this difference was much leſs remarkable. The mallow was the only vegetable the leaves of which perſpired more by the upper than the inferior ſurface. The method which he employed to aſcertain the comparative effect of the two ſurfaces was to cover firſt one and then the other ſurface with oil. The leaves were then immerſed in tubes filled with water, and the quantity of the perſpired matter was meaſured by the length of the tube emptied in a given time. The oil, by ſtopping up the pores, prevented perſpiration from the ſurface to which it was applied. Some large leaves of the white mulberry-tree being kept ſuſpended on water with their upper ſurfaces in contact with the fluid, faded in five days; ſome leaves of the ſame tree, being placed in a ſimilar ſituation, but with the inferior ſurface touching the water, were preſerved green for nearly ſix months.

The ſexual ſyſtem has been the faſhionable ſyſtem of botany for many years. It is well known that the palm is of that claſs of vegetables which has flowers of different ſexes on different trees. The peaſants in the Levant, whether acquainted with this fact, or whether directed to the practice by accident alone, have been accuſtomed to break branches from the male palm while in flower, and attach them to the female plant, which they find to be conſtantly productive of an abun-

dant

dant crop. This fact has alſo been proved by a moſt deciſive experiment of M. Greditſch. There was in the royal garden at Berlin a beautiful palm-tree, a female plant, which, however, though twenty-five years old, had been always barren. There was another palm at Leipſic of the male kind, which bloſſomed every year. This ingenious botaniſt undertook to fecundate the palm at Berlin from that at Leipſic, and had ſome of the bloſſoms conveyed by the poſt. The conſequence was, that he produced that ſeaſon excellent dates; and the experiment, proſecuted with ſome variation for ſeveral ſucceeding years, was attended with the ſame ſucceſs *.

It has been ſaid, that the pollen was deſtined for the impregnation of the germen. This is performed in the following manner. The antheræ, which at the firſt opening of the flower are whole, burſt ſoon after, and diſcharge the pollen. Being diſperſed about the flower, part of the pollen lodges on the ſurface of the ſtigma, where it is detained by the moiſture with which that part is covered. Each ſingle grain or atom of the pollen has been obſerved by the microſcope to burſt in this fluid, and is ſuppoſed to diſcharge ſomething which impregnates the germen below: what the ſubſtance is which is ſo diſcharged, and whether it actually paſſes through the ſtyle into the germen, ſeems yet undetermined, from the great difficulty of obſerving ſuch minute parts and operations. In ſome vegetables, the ſtamina move towards the piſtillum; and a very evident motion of them is obſerved in the flowers of the common berberry, on touching them with the point of a pin.

* Bonnet Contemp. p. 6.

The

The NOURISHMENT of vegetables, as it is ſo intimately connected with the important ſcience of agriculture, has deſervedly attracted conſiderable attention. Mr. Boyle dried in an oven a quantity of earth proper for vegetation, and, after carefully weighing it, planted in it the ſeed of a gourd; he watered it with pure rain-water, and it produced a plant, which weighed fourteen pounds, though the earth had ſuffered no ſenſible diminution.

A willow-tree was planted by Van Helmont, in a pot, containing 100 pounds of earth. This was in general watered with diſtilled water, or ſometimes with rain-water, which appeared perfectly pure. The veſſel containing the plant was covered in ſuch a manner as totally to exclude the entrance of all ſolid matter. At the end of five years, upon taking out the plant, he found it to have increaſed in weight not leſs than 119 pounds, though the earth had loſt only two ounces of its original weight.

Theſe experiments would admit of ſome doubt, and muſt have remained in a great meaſure inexplicable, but for the experiments of Mr. Cavendiſh, and the facts related by Dr. Prieſtley, which place it beyond a doubt, that vegetables have a power of decompoſing water, and converting it, with what they derive from the atmoſphere, into almoſt all the different matters found to exiſt in their ſubſtance. For the products of wood in diſtillation, I muſt refer the reader to what has been advanced in the chapter on carbon, or the carbonaceous principle.

All the proper juices of vegetables depend on the organization, as is evident from the operation of grafting. From the materials of ſimple water and air, are produced thoſe wonderful diverſities of peculiar juices and fruits, which the vegetable world affords; and the

immenſe variety of taſtes, ſmells, &c. In the ſame vegetable what a variety is found! The bark is different in taſte from the wood, the peculiar juices have ſomething different from them both, and the pith of plants affords a matter which could not have been expected from their exterior properties. The root is often different from the ſtem, and the fruit from both, in all their ſenſible qualities.

In whatever way the nouriſhment of vegetables is received, it may fairly be ſaid to conſiſt principally of water. I am inclined to believe, however, that calcareous earth, in ſmall portions, may enter into the compoſition of at leaſt many vegetables; ſince animals which exiſt entirely on vegetable food are found to have in their ſolid parts, the bones for inſtance, a conſiderable portion of this ſubſtance; though it muſt be confeſſed, that chemical analyſis, as far as it has hitherto gone, does not warrant us in ſuppoſing calcareous earth to be an eſſential conſtituent of all vegetable matter. It may be ſaid further, that on ſome occaſions the addition of other matters, as of different kinds of manure, adds greatly to the growth of vegetables; but in whatever degree a rich ſoil or dung may add to the luxuriance of growth, other facts ſeem to prove that it is not eſſential to vegetation. It is well known that many herbs flouriſh in pure water, and that pear, plum, and cherry trees, planted in pure moſs, have arrived at ſuch perfection as to produce good fruit *.

Different

* It is but fair to inſert the following fact, which ſeems to favour the neceſſity of carbonic matter to the growth and increaſe of at leaſt ſome ſpecies of vegetables.

" M. Ruchert is perſuaded that earth and water, in proper proportions, form the ſole nutriment of plants; but M. Giobert has clearly ſhewn the contrary; for, having mixed pure earth of allum,

Different theories have been advanced, to account for the operation of manures in promoting the growth of vegetables, none of which seem altogether satisfactory. The common opinion is, that the substances employed as manures are the food of plants, and are absorbed by their roots. This hypothesis may be true to a certain extent, when applied to some manures, but cannot be true with regard to them all; for it is well known, that not only chalk and lime, but even flints, are very beneficial to some soils. Another opinion is, that manures act by bringing soils to such a consistence as is favourable to the growth of the roots of vegetables, and to the affording of them water in a proper quantity. A third opinion is, that manures act as stimuli on the roots of vegetables, and thus excite them to more vigorous action. Some authors think that manures act as solvents on matters previously contained in the soil, and thus fit them for entering the roots of plants; and others, that they act chemically, by forming combinations which are favourable to vegetation. Which of these hypotheses is best founded, it is difficult to determine; but it does not seem unlikely that they may be all true to a certain extent.

When we attempt to discover the component principles of the objects around us, and the sources whence they are supported, we are lost in the greatness and diversity of the scenes presented to us. We see animals nourished by vegetables, vegetables apparently by the remains of animals, and fossils composed of the relics

allum, silex, calcareous earth, and magnesia, in various proportions, and moistened them with water, he found that no grain would grow in them; but when they were moistened with water from a dunghill, corn grew in them prosperously. Hence the necessity of the carbonic principle is apparent!"—*Kirwan on Manures*, p. 42.

of

of both theſe kingdoms. It is certain, however, that vegetables muſt in every part of the globe have preceded animals. A ſeed of moſs lodging in a crevice of a bare rock is nouriſhed by the atmoſphere, and the moiſture afforded by the rains and dews. It comes to perfection, and ſheds its ſeeds in the mouldering remains of its own ſubſtance. Its offspring do the ſame, till a cruſt of vegetable mould is formed ſufficiently thick for the ſupport of graſs and other vegetables of the ſame growth. The ſame proceſs going forward, ſhrubs, and laſtly, the largeſt trees, may find a firm ſupport on the once barren rock, and brave the efforts of the tempeſt.

From the advantages derived from a change of crops in agriculture, it has been ſuppoſed that different vegetables derive different kinds of nouriſhment from the ſame soil, ſelecting what is beſt adapted to their own ſupport, and leaving a ſupply of nouriſhment of another kind for vegetables of a different ſpecies. Was this, however, the caſe, vegetables would not ſo much impede each other's growth when placed near together. And in the operation of grafting, we have a clear proof, that the juices received by the root of one ſpecies of tree may, by the organization of the inſerted twig, be ſubſervient to the growth of leaves, flowers, and fruit of a different kind. The advantage derived from a change of crops may be better explained on other principles: ſome plants extend their roots horizontally on the ſurface of the ſoil, others ſtrike them downwards to a conſiderable depth. Some plants are found to bind or harden the ſoil, others to looſen it. Thus, for example, wheat and rye-graſs render a ſoil ſtiff, while pulſe, clover and turnips pulverize it. By varying the crops, therefore, the ſoil is preſerved in a middle ſtate, between too much ſtiffneſs and too much friability. Nor is this the only good effect ariſing from

this difference of roots. From this circumſtance ſome vegetables draw their nouriſhment from the ſurface of the earth, while others derive it partly from a greater depth. So that by a change of crops, a larger portion of the ſoil is made to contribute to the nouriſhment of plants than could have been effected by the cultivation of any ſingle ſpecies. One other advantage to be derived from a change of crops, is this: ſome plants extract almoſt the whole of their nouriſhment from the ſoil; and this is particularly the caſe with thoſe which are moſt valuable, and which contain the greateſt quantity of ſolid matter. By the repetition of ſuch crops, however, the ſoil is found to become too much exhauſted. There are other plants which derive a large proportion of their nouriſhment from the air; by ſuch therefore the ſoil will be much leſs exhauſted, and under a crop of them will be in ſome meaſure at reſt. The good effects of a change of crops may therefore be ſufficiently explained, without ſuppoſing that each particular ſpecies of vegetables is nouriſhed by a different kind of food. This opinion is alſo neceſſarily attended with two great difficulties: one is, that there exiſts in every ſoil as many diſtinct kinds of nouriſhment, as there are ſpecies of plants capable of growing in that ſoil; the other, that plants are endued with the faculty of diſcerning and ſelecting, from all theſe kinds, their own proper nouriſhment. The former of theſe ſuppoſitions is too abſurd to merit the leaſt attention, and the latter has been diſproved by actual experiment, ſince plants are not able to prevent their roots from abſorbing ſuch matters as prove poiſonous to them. Other writers, however, have been more moderate, and though they have rejected the idea of ſpecific nouriſhment in general, have nevertheleſs imagined that the hypotheſis might be well founded with reſpect

to

to particular ſpecies of vegetables. This they infer from the exiſtence of ſpecific manures, as ſoot for ſaintfoin, aſhes for white clover, and ſome others. It does not ſeem poſſible, however, to draw a line of diſtinction; and if we reject the idea of a ſpecific nouriſhment in general, we cannot admit it in particular inſtances.

In order to diſcover whether plants have an actual power of diſtinguiſhing matters preſented to their roots, a friend, who aſſiſted me in compiling this part of the work, made, among others, the following experiment.

A vigorous plant of mint was placed in a two-ounce phial, filled with filtrated well-water, to which were added four drops of a moderately ſtrong ſolution of ſal martis. On examining the plant the following day, no other effect was obſerved, than that the very tips of the radicles were withered and black. Four more drops of the ſolution were now added. On the third day the appearances were the ſame; and no new change taking place on the fourth, twelve more drops of the ſolution were added. On the fifth day the roots appeared of a yellowiſh green colour, and the top drooped very much. The larger leaves were pretty much withered and blackened. The abſorption of the water appeared to be in ſome meaſure impeded, but not entirely prevented. On the ſixth day the whole plant was withering very faſt; the roots became of a dark olive-green colour, and the larger leaves were become very black, eſpecially the foot-ſtalks and the projecting fibres. On the ſeventh day the blackneſs had made ſtill further progreſs, and the plant was dead. A ſufficient proof that ſome of the iron was abſorbed by the plant, may be drawn from the following circumſtance—its leaves when ma-

cerated in diſtilled water, produced a black colour with galls. The leaves of a plant of mint, which had been nouriſhed by water alone, when tried by the ſame teſt, produced no colour whatever. Trifling as this experiment may appear, it proves two points; that plants have not the power of rejecting even injurious matters when preſented to their roots; and that other matters beſides water and air are capable of being abſorbed by them.

Agriculture ſeems yet to be nearly in its infancy, and even the benefit produced by the common cuſtom of letting lands lie fallow, has not yet been ſatisfactorily explained. Something may no doubt be attributed to the deſtruction of weeds, but more probably to ſome change produced in the ſoil by its being expoſed to the action of the ſun and air. The management of nitre-beds may tend to throw ſome light on this ſubject. Theſe are compoſed of calcareous earth and dung cemented together. After being expoſed for ſome months to the air, they are found to contain a quantity of nitrous acid, which, uniting to the calcareous earth, forms a kind of ſalt, which is extracted by lixiviation. Now calcareous earth and dung are two of the moſt powerful kinds of manure, and it does not ſeem improbable that their fertilizing powers may be in ſome manner connected with their property of affording nitrous acid.

CHAP. IV.

VEGETABLE SUBSTANCES.

Of the moſt remarkable Vegetable Productions.—Vegetable Oxyds.—Vegetable Acids.—Other eſſential Salts of Vegetables.

IT has been already remarked, that the ſimple component principles, which are eſſential to the formation of vegetable matter, are but three in number, namely, carbon, hydrogen, and oxygen. From the various proportions in which theſe ingredients are combined, reſults almoſt all the variety of vegetable matters which fall under our notice. Sugar, mucus (under which term I include the different kinds of gums, and ſtarch) are vegetable oxyds, having hydrogen and charcoal combined, in different proportions, as their radicals or baſes, and united with oxygen, ſo as to bring them to the ſtate of oxyds. From the ſtate of oxyds they are capable of being changed into that of acids, by the addition of more oxygen; and according to the degrees of oxygenation, and the proportion of hydrogen and charcoal in their baſis, they form the ſeveral kinds of vegetable acids. On the other hand, gum by being deprived of oxygen is capable of affording oil. M. Woulfe has found that a pound of gum arabic diſtilled with a quarter of a pound of vegetable alkali, furniſhes a conſiderable quantity of oil. The liquor which riſes along with it is not at all acid; therefore the acid of the gum remains united with the alkali. Honey afforded copiouſly an oil, when ſubmitted to the ſame proceſs.

The following are all the vegetable acids hitherto known.

1. Acetous acid, or vinegar.
2. Oxalic acid, or that of ſorrel and ſugar.
3. Tartarous acid.
4. Pyro *, or empyreumatic, tartarous acid.
5. Citric acid, or that of lemons.
6. Malic acid, or that of apples.
7. Pyro-mucous acid.
8. Pyro-ligneous acid.
9. Gallic acid, or that of galls.
10. Benzoic acid, or that of gum Benjamin.
11. Camphoric acid.
12. Succinic acid, or that of amber.

Nitrous acid, repeatedly diſtilled with gums, mucilages and ſugar, is decompoſed, the azote in part eſcapes, and the oxygen uniting with the inflammable matter of theſe ſubſtances, produces the acid of ſugar. By a continuation of the proceſs, however, the hydrogen and charcoal of the mucilaginous matters are ſeparated; the charcoal, combining with the oxygen, forms carbonic acid gas, and the hydrogen either eſcapes in the ſtate of inflammable air, or, attracting part of the oxygen, forms water. From this view of the ſubject, together with other facts, it has been inferred, that a greater or leſs proportion of vital air, united with the other two general principles of vegetables, hydrogen and charcoal, produces all the various acids of vegetables. Thus tartar is ſaid to have been converted into the acid of apples, by treatment with

* Pyro from the Greek πυρ (fire) means any thing prepared or extracted by fire.—Empyreumatic has the ſame etymology and meaning.

nitrous

nitrous acid. The acid of apples, by the continuance of the operation, becomes converted into acid of ſugar, or acid of ſorrel, which are the ſame thing. The ſame proceſs further continued, affords vinegar. Hence it ſhould ſeem that according to the greater progreſs of the operation of combuſtion, or the combination of vital air with the baſis, the acids of tartar, of apples or unripe fruit, of ſorrel or ſugar, of vinegar, and laſtly of charcoal, are produced. In this order of proceeding, the acids become more and more perfect, and leſs eaſily decompoſable; and it probably proceeds from this cauſe, that the reverſe of theſe proceſſes could never be completely accompliſhed.

Profeſſor Murray, of Gottingen, has aſſured us, that he has obtained acid of ſugar by repeated diſtillations and congelation, without uſing nitrous acid. Abbè Fontana obtained an acid perfectly like that of ſugar from all the gums and reſins. Mr. Watt of Birmingham, when making ſome experiments relative to ink, obſerved a number of particles floating in the fluid, which had the ſhape of cryſtals of the ſaccharine acid, and upon examination were found to be really ſuch; and, conducting the proceſs in the uſual way with the nitrous acid, he found that aſtringent vegetable matters contain the acid of ſugar in greater abundance than that ſubſtance from which it derives its name.

Theſe ſaline matters are called eſſential ſalts of vegetables. There are ſome others which are alſo called eſſential ſalts, but are not peculiar to vegetables. Such as the fixed vegetable alkali, which may be extracted by incineration from plants in general, and the fixed foſſil alkali, which is only extracted from

marine plants. Several neutral ſalts may alſo be extracted from particular vegetables: as vitriolated tartar from millefoil, and from aſtringent and aromatic plants; Glauber's ſalt from tamariſk; common ſalt and muriat of pot-aſh from marine plants. Many other ſalts will doubtleſs be found, when a greater number of plants ſhall be accurately analyſed.

Chap. V.

OF THE MORE SIMPLE VEGETABLE COMPOUNDS.

Gum.—Gum Arabic.—Gum Tragacanth.—Common European Gum.—Sugar; obtained from most Vegetables.—Process of making Sugar.—Manna—Fat, or expressed Oils.—Chocolate.—Vegetable Wax.—Analysis of Olive Oil.—Essential Oils.—Of Cinnamon.—Of Balm, Peppermint and Wormwood.—Of Lavender.—Of Roses.—Of Aniseed.—Of Parsley.—Of Camomile.—Of Sassafras and Carraway.—Of Nutmeg. Pepper and Mace.—Balsams.—Balsam of Tolu.—Benzoin and Storax.—Camphor. Resins.—Gum Copal.—Catchouc or elastic Gum..—Fecula.—Briony.—Potatoes.—Sago.—Salep.—Farina or Flour.—Gluten.—Starch.—Saccharine Matter of Wheat.—Bread.—Colouring Matters of Vegetables.—Principles of the Art of Dying.—Arnotto.—Bastard Saffron.—Archil.—Indigo.—Alkanet Root.—Luteola.—Madder.—Walnut.—Alder.—Sumach, &c.—Galls.—Lakes.

THERE are certain compound substances, which are formed by the process of vegetation, and may be obtained without the application of any greater heat than that of boiling water, or the action of any other solvents, than water and ardent spirit. These substances may be referred to the following heads:—1. Gum. 2. Sugar. 3. Fat Oils. 4. Essential Oils. 5. Balsams. 6. Camphor. 7. Resin. 8. Pure fecula of vegetables. 9. Farina. 10. Vegetable colouring matters.

I. Gum.—Its characters, when in its purest state, are those of a substance inodorous, insipid, generally solid, of more or less transparency, with sometimes a slight

ſlight tinge of colour, generally yellow; eaſily ſoluble in water into a viſcid liquor, called mucilage, in which ſtate it originally exiſted in the vegetable; not acted on by ſpirit of wine or oils; not volatile in the heat of boiling water, nor fuſible in any heat, but ſubject to the ſame changes as other vegetable matter.

Gum, in its dry and ſolid ſtate, is not in the leaſt acted on by oils, but mucilage manifeſts a conſiderable diſpoſition to unite with them. Gum is not a ſolvent of reſinous or balſamic matter; this matter will, however, be diſſolved in water, in conſequence of being added to gum, eſpecially by the aſſiſtance of agitation. Thus oils and balſams may in many caſes be combined with water, and remain combined with it, forming a milky ſolution, particularly if the quantity of gum is conſiderable. This kind of combination is very frequent in plants. There are many in which oil and gum are naturally united. The uſeful juice of the poppy is of this kind, and from ſuch compounds gum-reſins are obtained, by the evaporation of their watry parts. Theſe compounds have ſtill ſolubility in water, though the gum is the part chiefly diſſolved; the reſinous part is either left in its concrete ſtate, or being merely ſuſpended, and not diſſolved, its particles are interpoſed between thoſe of the gum and water, and occaſion a degree of opacity. Such ſubſtances alſo in their ſolid ſtate as conſiſt of a mixture of gum and reſin are always opake, while the pure gums and pure reſins have more or leſs of tranſparency.

Gum is very abundant in the vegetable kingdom; it is found in a great number of roots; the young ſhoots and young leaves contain it in large quantities, and its preſence may be known by its viſcous and adheſive quality, when theſe parts are cruſhed between the fingers. Gum is uſually obtained by wounding

the bark of particular trees. It is obſervable, that ſaccharine fruits, when ſour and unripe, are found to contain gum and an acid; whence it ſeems not unfair to conclude, that ſaccharine matter is formed of theſe materials, operated on by the proceſs of vegetation.

The moſt common gums are—1. Gum Arabic, which flows from the acacia in Egypt and Arabia, and is of the ſame nature with gum Senegal, which is ſometimes ſold inſtead of it. 2. Gum tragacanth, which is obtained from a thorny buſh, growing in Crete, Aſia, and Greece. 3. The gum which flows from certain trees growing in this country, particularly apricot and plum-trees. The eſſential characters of all theſe gums are the ſame, but gum tragacanth is by far the moſt powerful in producing a thick and tenacious mucilage.

II. Sugar. —The mixed and various properties of this ſubſtance, have rendered chemiſts very doubtful to what claſs of bodies it ought to be referred. By ſome it has been called inflammable, by others ſaline, and by others it has been claſſed among gummy and mucilaginous matters. Sugar is ſoluble, both in water and ardent ſpirit. It is more inflammable than gums, and has not been proved to contain any ſalt ready formed, except ſome fixed alkali. It is the only principle the preſence of which enables fluids to take on the vinous fermentation.

Saccharine matter is found in a great number of vegetables; ſuch as the maple, the birch, the red beet, the parſnip, the grape, farinaceous grain, potatoes: Margraff indeed extracted it from moſt vegetables; and it is well known that honey is a ſaccharine matter, collected by the inſtinct of the bee from an infinite variety of plants, but principally from flowers. The arundo ſaccharifera or ſugar-cane contains this matter

however

however in larger quantities, and affords it more readily, than any other plant. The ripe canes are twice crushed between iron cylinders, by which they are squeezed completely dry, and sometimes even reduced to powder. The cane juice or melasses is received in a leaden bed, and thence conveyed into a vessel called the receiver; thence it runs to the boiling-house, where it is received into a copper pan or caldron, which is called a clarifier. Of these there are generally three, and their dimensions are determined by the extent of the owner's plantation. Methods of quick boiling are indispensably necessary, as the purest cane juice will not remain twenty minutes in the receiver, without fermenting and becoming tainted. As soon as the stream from the receiver has filled the boiler or clarifier with fresh liquor, and the fire is lighted, the temper, which is generally Bristol white lime in powder, is stirred into it. This is done in order to neutralize the superabundant acid, to get rid of which is the great difficulty in making sugar. As the force of the fire increases, a scum is thrown up, which proceeds from the gummy matter of the cane, with some of the oil, and such matters as are entangled in the mucilage. The heat is now suffered to increase gradually, till it approaches to that of boiling water; but it must by no means be suffered to boil. When the scum begins to rise into blisters, and break into white froth, which generally appears in about forty minutes, it is known to be sufficiently heated. The fire is then extinguished, and, if circumstances will admit, the liquor is left a full hour undisturbed. The liquor is now carefully drawn of, so as to leave the scum, and conveyed by a gutter to the evaporating boiler; and if produced from good materials, and well managed, it will appear almost transparent. In this vessel it is suffered to boil, and the scum as it rises is

continually

continually taken off, till the liquor becomes finer, ſomewhat thicker, and almoſt of the colour of Madeira wine Being transferred to a ſmaller copper, the boiling and ſcumming are continued; and if the liquor is not ſo clear as might be expected, lime-water is added, which thins the mixture, ſo as to ſuffer the impurities to riſe more readily to the ſurface. When, in conſequence of ſuch ſcumming and evaporation, the liquor is ſo reduced that it can be contained in the third copper, it is laded into it, and ſo on to the laſt copper, which is called the teache. This arrangement ſuppoſes four coppers, beſides the three clarifiers.

In the teache the liquor undergoes another evaporation, till it is ſuppoſed to be boiled enough to be removed from the fire.

The cooler (of which there are generally ſix) is a ſhallow wooden veſſel, about eleven inches deep, ſeven feet in length, and from five to ſix feet wide. A cooler of this kind holds a hogſhead of ſugar. Here the ſugar grains, that is, as it cools it runs into a coarſe irregular maſs of imperfect cryſtals, ſeparating itſelf from the melaſſes. From the cooler it is taken to the curing-houſe, where the melaſſes drains from it. When it is cooled ſo that the finger may be plunged into it without injury, it is poured into barrels, placed over certain ciſterns, and pierced at the bottom with many holes, imperfectly ſtopped with the ſtalk of a plantain leaf, through which the ſyrup drains. In the ſpace of three weeks the ſugar becomes tolerably dry and fair. It is then ſaid to be cured, and the proceſs is finiſhed. The ſugar thus obtained is called *muſcovado*, and is the raw material whence the Britiſh ſugar-bakers chiefly make their loaf or refined lump. The juice of the ſugar-cane contains a ſuperabundance of acid, which prevents the dry concretion. In order to get rid of

this,

this, they employ lime-water, as the faccharine acid is feparated by its means from every other combination. The lime powerfully attracting the acid when united with it, forms an infoluble falt, which either falls to the bottom or mixes with the fcum. Many perfons have fuppofed that a portion of the lime remains mixed with the fugar; but Bergman affures us, that if the purification is properly conducted, the nature of the ingredients, the circumftances of the operation, and finally the moft accurate analyfis, abundantly fhew, that there is not the fmalleft trace of lime remaining. Good fugar diffolves totally in diftilled water, which could not poffibly be the cafe if there was prefent any lime, either in a feparate ftate or united with the faccharine acid.

There is another fort of fugar, which is much ufed, and which in England paffes by the name of Lifbon fugar, but which in the Weft Indies is called *clayed* fugar; the procefs for making it is as follows:—A quantity of fugar from the cooler is put into conical pots or pans, with the point downwards, having a hole about half an inch in diameter at bottom, for the melaffes to drain through, but which is at firft ftopped with a plug. As foon as the fugar in thefe pots is cool, and becomes a fixed body, which is known by the middle of the top falling in, the plug is taken out, and the pot placed over a large jar, intended to receive the fyrup which flows through. In this ftate it is left as long as the melaffes continues to drop, when a ftratum of moiftened clay is fpread on the fugar. The water gradually draining from the clay, dilutes the melaffes, in confequence of which more of it comes away from the fugar, which becomes whiter and finer. A fecond covering of clay is put on when the firft is dry, and water is again fuffered to filter through, after which the

the loaves are carried to an oven to dry. At the end of eight or ten days theſe loaves are broken, and the powdered ſugar is conveyed to Europe.

Certain juices which flow out of plants are of a ſaccharine nature; ſuch is manna, which is produced by the pine, the fir, the oak, the maple, the juniper, the fig, the willow, &c.; but the aſh, the larch, and the alhagi afford it in the largeſt quantities. Robel, Rondelet, and others, have obſerved at Montpelier, upon the olive trees, a kind of manna, to which they have given the name of *oeliomeli.* Tournefort collected it from the ſame trees at Aix and Toulon. The aſh, which is very abundant in Calabria and Sicily, affords the manna of commerce: it flows ſpontaneouſly from theſe trees, but is much more abundantly collected by making inciſions in the bark. That which is procured by introducing chips of wood or ſmall ſticks into artificial apertures, forms a kind of ſtalactites, perforated within, and called manna in the tear. Manna in flakes flows from the bark, and contains ſome impurities. Manna affords, by treatment with the nitrous acid, the ſame acid as is obtained from ſugar.

III. Fat Oils are not emitted from the ſurface of vegetables, but are obtained by preſſure from their emulſive ſeeds or kernels. They feel ſmooth to the touch, are generally, when recent, without ſmell or taſte, and are inſoluble in water. They are not volatilized but by a heat conſiderably ſuperior to that of boiling water, and do not take fire till ſufficiently heated to be volatilized. When they are burned on the wick of a lamp, ſmall portions are ſucceſſively brought to its extremity, and being there volatilized, undergo inflammation. Moſt fat oils are fluid, and require a conſiderable degree of cold to congeal them; others become

come ſolid by a very ſlight degree of cold; and others again are almoſt always ſolid: theſe laſt are called butters. Such are thoſe of the cacao nut, from which chocolate is made, and alſo of the cocoa-nut. Vegetable wax is of the ſame nature, only more ſolid. It is the production of China; and is there made into yellow, white, or green candles, the colour varying according to the manner in which the wax is extracted. The catkins of birch and poplar afford a ſmall quantity of a ſimilar wax. M. Berthollet eaſily whitens it with oxygenated muriatic acid.

Fat oils expoſed to the air attract its oxygen, and become acid or rancid. Water and ſpirit of wine, by abſtracting this acid, deprive them of their ſtrong taſte, but never completely reſtore them to their original ſtate. M. Berthollet has diſcovered that fat oils, thinly ſpread on the ſurface of water, and expoſed to the air, become thick, and aſſume the appearance of wax. This appears to ariſe from the abſorption of oxygen, as the oxygenated muriatic acid produces this change more ſuddenly.

Theſe oils afford by diſtillation a ſmall quantity of water impregnated with a peculiar acid, a light oil, a denſe oil, and inflammable and fixed airs. The quantity of charcoal left behind is not abundant. By rediſtilling the firſt products, more water, and an oil which becomes lighter each time, are obtained. Lavoiſier collected the products of olive-oil burned in an apparatus properly conſtructed to aſcertain their nature and properties. He obtained ſeventy-nine parts of carbon, and twenty-one of hydrogen, from one hundred of oil. From theſe component parts, inferences may be drawn reſpecting the acid, the water, the fixed air, and the inflammable air, afforded by partial decompoſitions or combuſtions of this fluid. When

oils

oils are burned in pure air, one of their component principles, hydrogen, is combined with pure air, and forms water; while charcoal, its other component part, combines with pure air alſo, and forms fixed air.

The denſe animal oils, ſuch as butter, tallow, fat, and the oil of the whale, exceedingly reſemble vegetable fixed oils. They appear, however, to contain a proportion of azotic air and animalized matter, probably in the ſtate of ſerum or jelly.

Agitation in water ſeparates a mucilaginous matter from fat vegetable oils, which ſeems to be the cauſe of their becoming rancid. They combine with pure fixed alkalies into ſoap, and they alſo unite with magneſia and lime, which form with them ſoapy compounds.

IV. Essential Oils are remarkable for a ſtrong aromatic ſmell, and are ſufficiently volatile to riſe with the heat of boiling water. They are in general ſoluble in ſpirit of wine, and their taſte is very acrid. They are much more inflammable than the fat oils.

Eſſential or volatile oils exiſt in moſt fragrant vegetables, and in various plants are found in different parts; thus the oil of cinnamon is found in the bark; of balm, peppermint, and wormwood, in the leaves; of the roſe and lavender, in the flower; of nutmegs, aniſe, and fennel, in the ſeeds. They are obtained either by expreſſion, as from the peel of oranges and lemons, or by diſtillation with water. For the latter purpoſe, the plant is put into a copper alembic, with water; the water being made to boil, comes over together with the oil into the receiver, and is obtained ſeparate by decantation. Some of the eſſential oils are fluid, as that of lavender; others congeal by cold, as that of anniſeed; others are always concrete or ſolid, as thoſe of roſes and parſley. They differ much with reſpect to colours: thus, oil of

lavender is yellow, that of cinnamon deep yellow, that of parsley green, that of camomile blue. Some of the essential oils float in water, as most of the oils obtained from plants growing in temperate climates; others, as those of sassafras and carraway-seeds, and most of the oils from hot countries, sink in that fluid. This property is not, however, invariable with respect to climate, as the essential oils of nutmeg, pepper, and mace, are lighter than water. It is remarkable, that essential oils sometimes entirely differ in their properties from the plant which affords them; thus, oil of pepper is mild, and oil of wormwood is not bitter.

The perfume, or principle of scent, in plants, to which Boerhaave gave the name of *spiritus rector*, seems in general to reside in the essential oil. It composes an extremely small part of the weight of vegetables, as may be inferred from the loss of fragrance sustained by essential oils with little or no loss of weight. It does not seem improbable, that the perfume, or principle of scent, in plants, is a gas of a peculiar nature. Its invisibility and volatility, the manner in which it is expanded and dispersed in the atmosphere, together with certain experiments made by Dr. Ingenhouz, on the noxious gas afforded by flowers, render this opinion very probable.

It is easy to discover the adulteration of volatile oils, either by pouring ardent spirit on them, which will not dissolve the fat oil they may be contaminated with; or if they are dropped on paper, and held to the fire, the essential oil evaporates, leaving the fat oil behind, which makes a greasy spot. If oil of turpentine is fraudulently added to them, its smell betrays its presence when treated in this manner. By

exposure to the air they become thick, and in process of time assume the character of resin. Needle-shaped crystals are deposited similar to those afforded by camphor when sublimed. Geoffroy the younger observed them in the essential oils of motherwort, marjorum, and of turpentine. The same chemist observes, that their smell is similar to that of camphor.

Essential oils combine very readily with sulphur, and form compounds called balsams of sulphur, in which the sulphur is so far changed that it cannot be recovered.

V. The proper vegetable BALSAMS are oily aromatic substances, imperfectly fluid, obtained by incisions made in certain trees. The word balsam has been used in a very extensive sense, to denote a variety of vegetable substances, which agree in consistence, though differing very widely in their nature and properties. This denomination, however, is more properly confined to such resinous matters as possess a fragrant smell, and more especially contain acid, odorant, and concrete salts, which may be extracted by decoction or sublimation; such as benzoin, balsam of Tolu, and storax.

VI. CAMPHOR is a peculiar vegetable substance, of a strong smell and taste, which resembles essential oils in some of its properties, and differs from them in others. It is much more volatile than the essential oils; with the most gentle heat it sublimes and chrystalizes in hexagonal laminæ attached to a middle stem. By a sudden heat it melts before it rises. Water does not dissolve it; but it is plentifully soluble in spirits of wine, æther, and concentrated acids, from the two former of which it is separated by the addition of water without alteration. Fixed and volatile oils dissolve

camphor with the affiftance of heat, and depofit cryftals in the form of a beautiful vegetation by cooling. A peculiar acid is formed by the diftillation of nitrous acid with this fubftance. Camphor has been obtained in fmall quantities from the roots of zedoary, thyme, rofemary, fage, anemony, and other vegetables, by diftillation. It is obfervable, that all thefe plants afford a much larger quantity of camphor, when the fap has been fuffered to pafs to the concrete ftate by feveral months drying. Thyme and peppermint, flowly dried, afford much camphor; and M. Achard has obferved, that a fmell of camphor is difengaged when volatile oil of fennel is treated with acids. M. Chaptal concludes, from thefe and fome other facts of the fame kind, that the bafis of camphor forms one of the conftituent parts of fome volatile oils, in which it exifts in the liquid ftate, and does not become concrete, but by combining with the bafis of vital air.

The camphor of commerce is obtained from a fpecies of laurel which grows in China, Japan, and in the iflands of Borneo, Sumatra, Ceylon, &c. The tree which produces it fometimes contains it in fo large a quantity, that it need only be cleft, in order to obtain very pure tears of camphor, of confiderable fize. The roots of this tree afford camphor in by far the greateft abundance, but it is alfo procured from the branches, trunk and leaves. The method of obtaining the camphor is by diftilling the different parts of the tree with water. The alembic in which the operation is performed is covered with a capital or head filled with ftraw. On the application of a fufficient heat, the camphor is fublimed in fmall greyifh grains, which are afterwards united into larger maffes. The camphor in this ftate is impure; it is purified after being brought to Europe, principally in Holland, where it undergoes fublimation in low flat-bottomed

glafs

glaſs veſſels. Chaptal ſays, that the Dutch mix an ounce of quick-lime with every pound of camphor previous to diſtillation.

VII. Resins are dried juices of plants, of the nature of eſſential oils. Almoſt all the concrete juices, diſtinguiſhed by the name of reſins, are ſoluble in ardent ſpirit, and not in water, whereas gums are ſoluble in water, and not in ſpirit. They uſually flow from wounds made in the trunks of trees purpoſely to obtain them. They are inflammable, and burn with much ſmoke. In cloſed veſſels they do not riſe wholly by heat, but are decompoſed. Reſins differ from balſams in their ſmell, which is leſs agreeable, and eſpecially in their containing no concrete acid ſalt. The common reſin of the pine, the reſin of the fir, pitch, tar, and turpentine, are perfect reſins, and are ſoluble in ſpirit of wine. Copal, and the elaſtic ſubſtance called *caoutchouc*, which is the inſpiſſated juice of an African tree, are uſually but improperly reckoned among reſinous ſubſtances; though neither ſpirit of wine nor water diſſolves them. They are ſoluble, however, in oils, by the aſſiſtance of heat, and have been thought to be of the nature of fat oils, though they differ in many remarkable properties.

The juices called gum-reſins, or the mixtures of gum and reſin, are not completely ſoluble either in water or ſpirit of wine. Both theſe menſtrua, however, by diſſolving one of the component parts, ſuſpend a portion of the other, from their intimate union.

VIII. Pure Fecula of Vegetables.—If the ſubſtance of a vegetable is reduced to a pulp by pounding, this pulp by ſtrong preſſure affords a turbid

white or coloured fluid, which by ſtanding depoſits a ſubſtance more or leſs fibrous or pulverulent, according to the nature of the vegetable ſubſtance from which it was obtained. This is called the fecula of vegetables, and conſiſts almoſt entirely of ſtarch. Some parts of vegetables appear to be altogether compoſed of this matter; ſuch as the ſeeds of the gramineous and leguminous plants, tuberous roots, &c. Theſe parts in general afford the fineſt and moſt abundant fecula. The ſtems and leaves of vegetables afford only a coarſe filamentous depoſition, but if this is powdered and waſhed, the water carries off a fine fecula, perfectly ſimilar to that afforded by grain. All vegetables therefore, and all the parts of them, afford more or leſs of this matter; the only difference is, that in ſome parts it is naturally diſengaged from other ſubſtances, in others it is in ſuch a ſtate, that it muſt be ſeparated by a laborious proceſs. The fecula of ſome vegetables is ſeparated as an article of food: as from the root of briony, from potatotes, from the root of a very acrid plant called manioc, from the pith of a kind of palm which grows in the Moluccas, which affords the fecula called ſago; and from the root of a ſpecies of orchis, which affords ſalep.

IX. Farina.—Flour, or the pulveriſed ſubſtance of farinaceous ſeeds, has a ſtrong analogy with the gummy and ſaccharine mucilages. Farinaceous ſeeds, if kept in a moderate temperature, and ſupplied with moiſture, are, by the incipient proceſs of vegetation, converted in a great meaſure into ſaccharine mucilages, as happens in making malt. Wheat-flour is the moſt perfect farina with which we are acquainted, and I ſhall therefore confine my deſcription to it; though it

muſt

muſt be confeſſed that this deſcription will not apply in all reſpects to the more imperfect ſpecies of farina.

If a handful of wheat-flour is taken and kneaded in a veſſel of water, underneath a ſtream from a cock, the water carries off a fine white powder, and the kneading muſt be continued till the water paſſes off clear. The flour is then found to be ſeparated into three ſubſtances; a greyiſh and elaſtic matter remaining in the hand, which is called the glutinous or vegeto-animal part; a white powder depoſited by the water, which is the fecula or ſtarch; and a ſubſtance held in ſolution by the water, which is of a ſaccharine mucilaginous nature.

The glutinous matter exiſted before in the flour in a pulverized form, and acquires its tenacity by imbibing a portion of the fluid, but is totally inſoluble in it. It has ſcarcely any taſte, is elaſtic, ductile, and of a whitiſh grey colour. When drawn out, it extends to the length of about twenty times its diameter before it breaks, and appears as if compoſed of fibres placed beſide each other, according to the direction in which it has been drawn. If the force ceaſes, it recovers its original form by its elaſticity. When dry it is ſemi-tranſparent, and reſembles glue in its colour and appearance. If it is drawn out thin when firſt obtained, it may be dried by expoſure to the air, and in that ſtate has a poliſhed ſurface, reſembling that of animal membranes. If it is expoſed to warmth and moiſture while wet, it putrefies like an animal ſubſtance. If this gluten in its dried ſtate is placed on burning coals, or held in the flame of a candle, it exhibits the characters of an animal ſubſtance; it crackles, ſwells and burns, exactly like a feather or piece of horn. By diſtillation it affords, like animal ſubſtances, alkaline water, concrete volatile alkali, and an empyreumatic

 oil.

oil. Its coal is very difficultly incinerated, aud does not afford fixed alkali.

From thefe facts it follows, that this fubftance is totally different from all the others known to exift in vegetables, and in many of its characters refembles the fibrous part of the blood. It is to this gluten that wheat-flour owes its property of forming a very adhefive pafte with water. This gluten does not appear to exift in any confiderable quantity in other farinaceous fubftances, as rye, barley, buck-wheat, rice, &c. M. Berthollet thinks that this glutinous fubftance contains phofphoric falt, like animal matters, and that this is the reafon of the difficulty with which it is incinerated. Rouelle the younger found a glutinous fubftance in the fecula of plants, analogous to that of wheat.

The powder which I remarked, as being feparated from the farina, and which, being only fufpended and not diffolved in the water, falls to the bottom by reft, is the amylaceous fecula or ftarch, which indeed compofes the greater part of the flour. This fubftance is very fine and foft to the touch; its tafte is fcarcely fenfible. When firft extracted by the procefs which has been defcribed, its colour is greyifh; but the ftarch-makers render it extremely white, by fuffering it to remain in the water for a time, after it has become acid.

Starch feems nearly allied to mucilaginous matters, and is totally different from the glutinous fubftance laft defcribed. Its habitudes and products with the fire, or with nitrous acid, are nearly the fame as thofe of gum and of fugar; but it differs from thefe fubftances in being fcarcely, if at all, acted on by cold water, though with hot water it forms a gelatinous fluid, It feems to be more remote from the faline ftate than gum, as gum is more remote from it than fugar. Starch burns without emitting an empyreumatic fmell. By diftil-

lation

lation with a naked fire, it affords an acid water of a brown colour, and a very thick oil towards the end of the procefs. Its coal is eafily reduced to afhes, which contain fixed alkali.

The fubftance which was mentioned as being diffolved in the water in which flour is wafhed, does not effentially differ from other faccharine mucilages. By evaporating the water in which it is contained, M. Poulletier obtained a vifcous, glutinous fubftance, of a brownifh yellow colour, and flightly faccharine tafte. This fubftance, called by its difcoverer the mucofo-faccharine matter, exhibited all the phenomena of fugar in its combuftion and diftillation. It is this which excites the acid fermentation in the water which floats above ftarch; for, as Macquer well obferves, the latter is not at all foluble in cold water. The mucofo-faccharine matter exifts in a very fmall proportion in wheat-flour. M. Fourcroy, however, is of opinion, notwithftanding the fmall quantity of it, that it is the part principally concerned in the fermentation by which bread is leavened.

With refpect to what is the nutrimental part of flour, all the fubftances into which it is refolved, by wafhing it in water, feem well adapted to this purpofe; but as the amylaceous matter is the moft abundant, fo it is probably the moft important ingredient. The amylaceous matter in wheat is to the glutinous in the proportion of about three to two.

Bread is the farina of grain, made into a pafte with water, and baked. Unleavened bread, or bifcuit, keeps longeft without fpoiling, and is therefore ufed at fea, where baking would be extremely inconvenient. Bread ufed on fhore is in general leavened, and for this purpofe a quantity of yeaft is added to it, while in the ftate of dough; in confequence of this, and of being

kept

ſtept in a warm temperature, it undergoes fermentation, attended with the extrication of air, by which the particles are ſeparated from each other, and the maſs ſwells and becomes more porous. This diſtenſion is ſtill further increaſed by the rarefaction of the air in baking, and thus is formed a ſubſtance much more miſcible with water than dough, and upon this latter property ſeems to depend its greater wholeſomeneſs, as being more digeſtible.

9. Colouring Matters of Vegetables. On a knowledge of the colouring matters of vegetables, depends the art of dying, which conſiſts in extracting from various ſubſtances colouring particles, and applying them to ſtuffs and other matters intended to be dyed, ſo that they ſhall adhere as firmly and durably as poſſible. Dyers enumerate five colours, which they call primary, from the mixture of which other colours are produced: theſe are blue, red, yellow, nut-colour, and black. Good dyes are thoſe which can reſiſt the action of water, air, and of certain ſaline and ſaponaceous liquors, which are uſed as the proofs of the durability of colours. Falſe dyes are thoſe which cannot reſiſt theſe proofs.

A great number of vegetable colouring matters, which are of an extractive or ſaponaceous nature, are readily diſſolved in water. The colouring principle of many other ſubſtances reſides in a purely reſinous matter, inſoluble in water, and in ſome inſtances attached to matters inſoluble, even in ſpirit of wine; but they are all acted on by alkalies, which convert them into a kind of ſoaps, miſcible with water. The principal colours of this nature are the annotto, a kind of fecula, obtained by maceration of the ſeeds of the urucu putrefied in water, and which dyes an orange yellow colour;

colour; the flower of carthamus or baſtard ſaffron, which affords a very fine red; archil, which is a paſte prepared with moſſes, macerated in urine with lime, and which dyes red. The colour of indigo alſo reſides in a reſinous matter.

Certain colouring ſubſtances are ſoluble in oils. Alkanet, or the red root of a kind of burgloſs, is of this kind, but cannot be uſed in dying.

We may eaſily conceive that a coloured decoction may ſtain any ſtuff which is dipped into it, and that this colouring matter may be again abſtracted by the application of the ſame menſtruum as it was originally ſuſpended in. But the action of thoſe dyes, which, although once diſſolved and ſuſpended in water, cannot again, after they are applied to ſtuffs, be waſhed out, is not ſo eaſily underſtood. Theſe latter, or durable dyes, alone deſerve attention. Dyes of different colours require different treatment. Stuffs to be dyed of a red or yellow colour muſt be boiled in water, with alum or fixed alkali, before they are dipped into the dying decoctions: the red colouring materials are kermes, cochineal, gum-lac, and madder; the yellow materials are luteola or dyers weed, and other yellow flowers. The ſtuffs for blue dyes require no previous preparation. Theſe blue dyes are made of indigo, or the blue fecula obtained from woad, diſſolved in a lixivium of fixed alkali, or in urine, with or without the addition of ſome green vitriol. The ſtuffs intended to receive a root colour, require no previous preparation, but to be ſoaked in warm water. Theſe dyes are chiefly decoctions of walnut-ſhells, walnut-roots, alder-bark, ſumach, and ſaunders. Theſe root colours, which are all yellow, ſerve to form a very good ground, on which other more brilliant colours may be applied, and to them no ſaline or other matter is added. The black dyes, which are inks or decoctions

of galls, mixed with green vitriol, require no previous preparation of the ſtuff.

It is obſervable that wool takes the dye better than ſilk, ſilk than cotton, and cotton than flax. Writers on the art of dying hold different opinions reſpecting the manner in which colouring particles apply themſelves to the ſubſtances expoſed to their contact. Many have ſuppoſed that this application takes place only in proportion to the number and magnitude of the pores in the various ſubſtances. Macquer, who has paid great attention to this ſubject, ſuppoſes that the greater or leſs facility with which the colour is applied, depends on the reſpective nature of the colouring parts, and the ſubſtances propoſed to be dyed: and that dying is truly an external tinge or painting, which ſucceeds and laſts by virtue of an affinity and intimate union between the colour and the dyed ſubſtance. This ſerves to explain the uſe of the matters, which it is on many occaſions neceſſary that the ſtuffs ſhould imbibe, previous to immerſing them in the dying ſubſtance. The ſame thing may be illuſtrated by conſidering the proceſs employed in the preparation of certain colours called lakes. Vegetable colouring matters are diſſolved, and then precipitated by the addition of ſome other ſubſtance. Thus, for example, if madder is boiled in water, together with an alkali, and alum is then added, the earth of the alum will be precipitated, together with the colouring matter, with which it will form an inſoluble pigment. A double decompoſition here takes place, the vitriolic acid quits the earth of alum to unite with the fixed alkali, and the vegetable matter unites itſelf with the earth.

CHAP. VI.

FERMENTATION.

Three Kinds of Fermentation.—The vinous or ſpirituous.—Spirit of Wine or Alcohol.—Ether.—Acetous Fermentation.—Putrid Fermentation.—Obſervations on Putrefaction in general.

HAVING conſidered the ſtructure and compoſition of vegetable ſubſtances, it becomes neceſſary to direct our attention to certain ſpontaneous changes which they undergo, when deprived of the vital principle. Theſe changes are called fermentations, which are three in number, and are termed, from their products, the vinous or ſpirituous, the acetous, and the putrid. The circumſtances univerſally neceſſary to fermentation are moiſture, a certain degree of heat, and the contact of air. The three kinds of fermentation are ſometimes conſidered as different ſtages of one proceſs; this, however, is an improper view of the ſubject, as each kind of fermentation is a peculiar proceſs, and totally different from every other. Some bodies become acid without having undergone the ſpirituous fermentation, and others putrify without ſhewing any diſpoſition to aſſume either that or the acetous ſtate.

The conditions neceſſary for the production of the VINOUS or ſpirituous fermentation are—1. A degree of fluidity ſlightly viſcid.—2. The preſence of ſaccharine mucilage. It is found that the fermentable juices of fruits, boiled till they become thick, are indiſpoſed to ferment, and this not only in their inſpiſſated ſtate, but when diluted again with water: for this reaſon it is, that in the making of ſugar nothing is of more importance than the juice of the cane being ſubmitted to

boiling

boiling immediately on being expreſſed. Preſerves, and other mixtures prone to fermentation, are prevented from that proceſs by the ſame method.—3. A proper temperature, which varies from forty-eight to eighty of Fahrenheit's thermometer. If below this, the fermentation is languid; if above it, it is impetuous, and is apt to ruſh into the acetous ſtate even before the vinous.—4. The addition of a quantity of the ſubſtance called yeaſt, which is itſelf the product of the vinous fermentation, is of great aſſiſtance in exciting it. By what power yeaſt acts in producing the vinous fermentation, has been much diſputed. Mr. Henry thinks that yeaſt is no other than fixed air already formed, but enveloped or entangled in the mucilaginous matter of the liquor from which it was obtained; and the ſame ingenious experimentaliſt was able to bring on the vinous fermentation, by adding to common wort a quantity of fixed air in the elaſtic form. To account for this, it is not difficult to ſuppoſe that fixed air has an attraction for its own conſtituent principles, when placed in favourable circumſtances to act upon them; and that it will thus occaſion the ſeparation of fixed air from the fermentable liquor, which is ſo remarkable during fermentation.

The phenomena which preſent themſelves in a liquor during the ſpirituous fermentation are—Firſt, A muddineſs, from the ſeparation of an aerial matter, which riſes in bubbles to the top in ſuch quantity, and in ſuch quick ſucceſſion, as to produce a hiſſing noiſe, and form a froth. Theſe minute globules of air occaſion the motion of the particles of the fluid among one another; and this motion is perceptible, even before the air is viſibly ſeparated. The globules of air attach themſelves to the particles of the mixture, and buoy them up; at length the globule is detached,

detached, and the atom ſinks by its own weight. The nature of the air which is diſengaged was not underſtood till the modern experiments on aëriform fluids afforded ſo much aſſiſtance to chemical ſcience. It is now aſcertained to be the carbonic acid gas, or fixed air, which, being heavier than atmoſpheric air, forms a ſtratum in the upper part of the veſſel in which the fluid is fermenting, where it may be perceived from its greater denſity. This air, contained in the fermenting vats of brewhouſes, frequently produces the moſt fatal effects on the workmen; and a candle dipped into it is as certainly extinguiſhed as if plunged into water. During the time that the fermentation is going on, the bulk of the liquid is augmented. Another phenomenon is the production of a gentle heat, equal to about ſeventy-two degrees of Fahrenheit's thermometer. After ſome days, the number of which varies according to the dilution of the ſubſtance and the degree of heat, the motion in the fluid diminiſhes, the warmth abates, and the emiſſion of air is leſſened; the liquor becomes clear, and the ſcum, which conſiſts of the more ſolid particles and air, becomes heavier in proportion as the air eſcapes, and at laſt ſinks. The liquor has now undergone a great change; it has acquired a pungent and pleaſant taſte and ſmell, and an inebriating quality, and has loſt its ſweetneſs. If the liquor is now diſtilled, inſtead of an inſipid matter, we obtain an ardent ſpirit, and a ſour, groſs fluid remains behind *.

By

* The phenomena of fermentation have long been known; but it remained for Lavoiſier to aſcertain with accuracy what happens in that proceſs. I ſhall therefore extract his experiments and concluſions, as ſtated by himſelf, in his Elements of Chemiſtry.

TABLE

By the experiments of Lavoisier, it appears that ardent spirit (alcohol) or the product of the vinous fermentation

Table I. *Materials of Fermentation.*

		libs.	oz.	gros	grs.
Water		400	0	0	0
Sugar		100	0	0	0
Yeast in paste, 10 *libs.* composed of	Water	7	3	6	44
	Dry yeast	2	12	1	28
	Total	510	0	0	0

Table II. *Constituent Elements of the Materials of Fermentation.*

		libs.	oz.	gros	grs.
407 *libs.* 3 *oz.* 6 *gros* 44 *grs.* of water, composed of	Hydrogen	61	1	2	71.40
	Oxygen	346	2	3	44.60
100 *libs.* sugar, composed of	Hydrogen	8	0	0	0
	Oxygen	64	0	0	0
	Charcoal	28	0	0	0
2 *libs.* 12 *oz.* 1 *gros* 28 *grs.* of dry yeast, composed of	Hydrogen	0	4	5	9.30
	Oxygen	1	10	2	28.76
	Charcoal	0	12	4	59
	Azote	0	0	5	2.94
	Total weight	510	0	0	0

Table III. *Recapitulation of these Elements.*

		libs.	oz.	gros	grs.	libs.	oz.	gros	grs.
Oxygen.	of the water	340	0	0	0	411	12	6	1.36
	of the water in the yeast	6	2	3	44.60				
	of the sugar	64	0	0	0				
	of the dry yeast	1	10	2	28.76				
Hydrogen.	of the water	60	0	0	0	69	6	0	8.70
	of the water in the yeast	1	1	2	71.40				
	of the sugar	8	0	0	0				
	of the dry yeast	0	4	5	9.30				
Charcoal.	of the sugar	28	0	0	0	28	12	4	59.00
	of the yeast	0	12	4	59.00				
Azote of the yeast						0	0	5	2.94
	In all					510	0	0	0

Having

mentation, confifts of the fame principles as fugar, except that they are combined in different proportions. Ardent fpirit contains more hydrogen, and lefs carbon and oxygen; which latter principles compofe the carbonic acid gas which efcapes during the fpirituous fermentation.* M. Lavoifier found that when ardent fpirit is burned in a chimney adapted to receive the vapours, a larger quantity of water is formed than the whole of the fpirit employed amounts to; whence it follows, that ardent fpirit contains a large proportion of

* Having thus accurately determined the nature and quantity of the conftituent elements of the materials fubmitted to fermentation, we have (adds M. L.) next to examine the products refulting from that procefs. For this purpofe, I placed the above 510 *libs.* of fermentable liquor in a proper apparatus, by means of which I could accurately determine the quantity and quality of gas difengaged during the fermentation, and could even weigh every one of the products feparately, at any period of the procefs I judged proper. An hour or two after the fubftances are mixed together, efpecially if they are kept in a temperature of from 15° (65.75°) to 18° (72.5°) of the thermometer, the firft marks of fermentation commence; the liquor turns thick and frothy, little globules of air are difengaged, which rife and burft at the furface; the quantity of thefe globules quickly increafes, and there is a rapid and abundant production of very pure carbonic acid, accompanied with a fcum, which is the yeaft feparating from the mixture. After fome days, lefs or more, according to the degree of heat, the inteftine motion and difengagement of gas diminifh; but thefe do not ceafe entirely, nor is the fermentation completed for a confiderable time. During the procefs, 35 *libs.* 5 *oz.* 4 *gros.* 19 *grs.* of dry carbonic acid are difengaged, which carry along with them 13 *libs.* 14 *oz.* 5 *gros.* of water. There remains in the veffel 460 *libs.* 11 *oz.* 6 *gros.* 53 *grs.* of vinous liquor, flightly acidulous. This is at firft muddy, but clears of itfelf, and depofits a portion of yeaft. When we feparately analyfe all thefe fubftances, which is effected by very troublefome proceffes, we have the refults as given in the following tables.

of hydrogen, which forms water, by combining with the vital air of the atmosphere during combustion. That it also contains a proportion of carbon, has been proved by M. Berthollet, who found that when a mixture of ardent spirit and water is burned, the residual fluid precipitates lime water, which must proceed from its containing some carbonic acid. Spirit of wine assumes

Table IV. *Products of Fermentation.*

		libs.	oz.	gros	grs.
35 *libs.* 5 *oz.* 4 *gros.* 19 *grs.* of carbonic acid, composed of	Oxygen - -	25	7	1	34
	Charcoal -	9	14	2	57
408 *libs.* 15 *oz.* 5 *gros.* 14 *grs.* of water, composed of	Oxygen - -	347	10	0	59
	Hydrogen - -	61	5	4	27
57 *libs.* 11 *oz.* 1 *gros.* 58 *grs.* of dry alkohol, composed of	Oxygen, combined with hydrogen -	31	6	1	64
	Hydrogen, combined with oxygen	5	8	5	3
	Hydrogen, combined with charcoal	4	0	5	0
	Charcoal, combined with hydrogen -	16	11	5	63
2 *libs.* 8 *oz.* of dry acetous acid, composed of	Hydrogen - -	0	2	4	0
	Oxygen - -	1	11	4	0
	Charcoal - -	0	10	0	0
4 *libs.* 1 *oz.* 4 *gros.* 3 *grs.* of residuum of sugar, composed of	Hydrogen - -	0	5	1	67
	Oxygen - -	2	9	7	27
	Charcoal - -	1	2	2	53
1 *lib.* 6 *oz.* 0 *gros.* 5 *grs.* of dry yeast, composed of	Hydrogen - -	0	2	2	41
	Oxygen - -	0	13	1	14
	Charcoal - -	0	6	2	30
	Azote - -	0	0	2	37
510 *libs.*	Total -	510	0	0	0

assumes the form of an elastic fluid at the temperature of 185 degrees.

Spirit

TABLE V. *Recapitulation of the Products.*

		libs.	*oz.*	*gros*	*grs.*
409 *libs.* 10 *oz.* 0 *gros.* 54 *grs.* of oxygen, contained in the	Water - -	347	10	0	59
	Carbonic acid - -	25	7	1	34
	Alkohol - -	31	6	1	64
	Acetous acid -	1	11	4	0
	Residuum of sugar -	2	9	7	27
	Yeast - -	0	13	1	14
28 *libs.* 12 *oz.* 5 *gros.* 59 *grs.* of charcoal, contained in the	Carbonic acid -	9	14	2	57
	Alkohol - -	16	11	5	63
	Acetous acid - -	0	10	0	0
	Residuum of sugar -	1	2	2	53
	Yeast - -	0	6	2	30
71 *libs.* 8 *oz.* 6 *gros.* 66 *grs.* of hydrogen, contained in the	Water - -	61	5	4	27
	Water of the alkohol -	5	8	5	3
	Combined with the charcoal of the alko.	4	0	5	0
	Acetous acid -	0	2	4	0
	Residuum of sugar -	0	5	1	67
	Yeast, - -	0	2	2	41
2 *gros.* 37 *grs.* of azote in the yeast	-	0	0	2	37
510 *libs.*	Total -	510	0	0	0

' In these results, I have been exact, even to grains; not that it is possible, in experiments of this nature, to carry our accuracy so far; but as the experiments were made only with a few pounds of sugar, and as, for the sake of comparison, I reduced the results of the actual experiments to the quintal or imaginary hundred pounds; I thought it necessary to leave the fractional parts precisely as produced by calculation.

' When we consider the results presented by these tables with attention, it is easy to discover exactly what occurs during fermentation. In the first place, out of the 100 *libs.* of sugar employed, 4 *libs.* 1 *oz.* 4 *gros.* 3 *grs.* remain, without having suffered decomposition; so that, in reality, we have only operated upon 95 *libs.* 14 *oz.* 3 *gros.* 69 *grs.* of sugar; that is to say, upon 61 *libs.* 6 *oz.* 45 *grs.* of oxygen, 7 *libs.* 10 *oz.* 6 *gros.* 6 *grs.* of hydrogen, and 26 *libs.* 13 *oz.* 5 *gros.* 19 *grs.* of charcoal. By comparing

Spirit of wine and the acids act with considerable violence on each other. When strong vitriolic acid is poured on an equal quantity of rectified spirit of wine, a strong heat, with a remarkable hissing noise, are excited; the two substances become coloured, and emit a sweet smell, resembling that of lemons, or the apple called golden rennet. If the mixture is made in a retort, and then submitted to distillation in the well-regulated heat of a sand bath, a large receiver, kept cool by the application of moistened cloths, being adapted, the volatile products may be condensed. These are: 1. Spirit of wine of a sweet smell. 2. A

these quantities, we find that they are fully sufficient for forming the whole of the alkohol, carbonic acid, and acetous acid produced by the fermentation. It is not, therefore, necessary to suppose that any water has been decomposed during the experiment, unless it is pretended that the oxygen and hydrogen exist in the sugar in that state. On the contrary, I have already made it evident that hydrogen, oxygen, and charcoal, the three constituent elements of vegetables, remain in a state of equilibrium or mutual union with each other, which subsists so long as this union remains undisturbed by increased temperature, or by some new compound attraction; and that then only these elements combine, two and two together, to form water and carbonic acid.

'The effects of the vinous fermentation upon sugar are thus reduced to the mere separation of its elements into two portions; one part is oxygenated at the expence of the other, so as to form carbonic acid, whilst the other part, being disoxygenated in favour of the former, is converted into the combustible substance alkohol; therefore, if it was possible to re-unite alkohol and carbonic acid together, we ought to form sugar. It is evident that the charcoal and hydrogen in the alkohol do not exist in the state of oil, they are combined with a portion of oxygen, which renders them miscible with water; wherefore these three substances, oxygen, hydrogen, and charcoal, exist here likewise, in a species of equilibrium or reciprocal combination; and in fact, when they are made to pass through a red hot tube of glass or porcelain, this union or equilibrium is destroyed, the elements become combined two and two, and water and carbonic acid are formed.

fluid

fluid called *ether*, extremely volatile, and alſo of a pleaſant odour: this comes over as ſoon as the fluid in the retort begins to boil, and the upper part of the receiver is at the ſame time covered with large diſtinct ſtreams of the fluid, which run down its ſides. 3. A light yellow oil, called ſweet oil of wine; and 4, a ſulphureous ſpirit paſſes over, the white colour and ſmell of which indicate the proper time for changing the receiver, in order to have the ether ſeparate; and this is ſucceeded by black and foul vitriolic acid.

Ether is a fluid of a peculiar nature. It is the lighteſt and moſt volatile of all unelaſtic fluids, and its tendency to aſſume the elaſtic form is ſo ſtrong, that it is quickly diſſipated in the ordinary heat of the atmoſphere, unleſs confined. It is highly inflammable, ſo that it is dangerous to bring a candle near any conſiderable quantity of it, the vapour taking fire, and communicating the inflammation to the whole volume. The acids with which ſpirit of wine is diſtilled, in order to obtain ether, ſeem to effect this principally by robbing the ſpirit of part of its carbon, which latter ſubſtance occaſions the dark colour in the mixture, by decompoſing the acid. A ſmall part of the acid adheres to the ether in its aſcent, and this conſtitutes the differences which exiſt among the ethers, according to the acid by which they were produced.

The Acetous Fermentation is ſtill more ſimple than the ſpirituous, and conſiſts merely in the abſorption of the vital or oxygenous part of the atmoſphere, by which vinous fluids are converted into vinegar; whence it appears that it is the proportion of oxygen alone which conſtitutes the vaſt difference that exiſts between ardent ſpirit and vinegar. That wine is converted into vinegar, by the addition of oxygen, is proved, as well from the general analogy of the for-

 mation

mation of other acids, as by the following direct experiments. In the firft place, we cannot change wine into vinegar, without expofing the former to the contact of air containing oxygen, or employing fome other mode of oxygenation; fecondly, this procefs is accompanied by a diminution of the volume of the air in which it is carried on, from the abforption of oxygen; and thirdly, wine, by being converted into vinegar, is increafed in weight.

The Putrid Fermentation is the deftruction of the equilibrium which holds the conftituent principles of bodies in a ftate of combination. Thus a vegetable fubftance, which when entire confifts of a triple combination of hydrogen, oxygen, and carbon, is refolved by putrefaction into hydrogen gas, and carbonic acid gas, which confifts of oxygen and carbon. As there is not enough of oxygen to convert all the carbon into carbonic acid gas, a quantity of the charcoal remains behind, mixed with the earthy and faline matter contained in the vegetable. Thus putrefaction in a vegetable fubftance, is nothing more than a complete analyfis of it, in which the conftituent elements are difengaged in the form of gas, except the earth, and a quantity of charcoal which remains in the ftate of mould.

Such is the refult of putrefaction when the fubftances fubmitted to it contain only oxygen, hydrogen, charcoal, and a little earth. But this cafe is rare; and thefe fubftances putrefy imperfectly, and with difficulty. It is otherwife with fubftances containing azote, which indeed exifts in all animal matters, and in a confiderable number of vegetables. The putrid fermentation of animal fubftances is commonly called putrefaction, and this is well known to take place in them, after they are deprived of life. The circumftances which favour putre-

putrefaction are the same as those which promote the spirituous and acetous fermentations, viz. humidity, the admission of air, and a due degree of heat. Heat to a certain degree promotes putrefaction, yet 20° above that of the human blood seems to prevent it. A small piece of fish which was luminous, and consequently putrid, was put into a thin glass ball, and water of the heat of 118° extinguished its light, and consequently stopped its tendency to putrefaction, in less than half a minute; on taking it out of the water, it began to recover its light in about ten seconds, but was never so bright as before *.

Azote, which abounds so much in animal substances, not only occasions a more rapid putrefaction, but renders its products considerably different from those afforded by the decay of such vegetables as do not contain azote. In the putrefaction of animal matters, the hydrogen, instead of escaping in a separate state, combines with the azote, and forms volatile alkali. The hydrogen gas also dissolves a part of the carbon, the sulphur, and the phosphorus, all which substances enter into the composition of animal matter; with these, it forms compound aeriform fluids, which have obtained the following names, carbonated hydrogen gas, sulphurated hydrogen gas, and phosphorated hydrogen gas. The two latter of these gasses have a peculiar, disagreeable odour, and, together with the volatile alkali, occasion the penetrating and offensive exhalations which proceed from putrid matters. Sometimes volatile alkali predominates; which affects the eyes; sometimes, as in feculent matters, the sulphurated gas is most prevalent; and sometimes, as in putrid herrings, the phosphorated hydrogen gas is

* Priestley's Hist. of Optics, p. 579.

most abundant. Carbonic acid gas is also disengaged. It appears highly probable, that water, which is so necessary to putrefaction, is decomposed during that process, and that its component principles, oxygen and hydrogen, contribute to the great quantity of gasses which are produced. Oxygen seems also to be absorbed from the atmosphere, since putrefaction is expedited by vital air.

M. Fourcroy and M. Thouret have observed some peculiar phenomena in dead bodies, buried at a certain depth, and preserved to a certain degree from contact of air: having found the muscular flesh converted into true animal fat. This must have arisen from the disengagement of the azote by some unknown cause, leaving only the hydrogen and charcoal remaining, which are the elements of fat or oil. This observation, M. Lavoisier remarks, may at some future period lead to discoveries of great importance to society, by enabling the chemist to convert into oil substances which consist of nearly the same principles, but which are at present of no value.

The decomposition of vegetable matters by fire, was noticed in treating of inflammable substances, in the chapter on carbon or the carbonaceous principle; and the mode of extracting from the ashes of certain plants that useful substance the fixed alkali, has been also described.

There is perhaps no process of nature better understood than that of fermentation, and yet there is not any more calculated to excite our astonishment; there is not any instance within my recollection so striking, of the surprizing change which combination produces in bodies; and it is the more wonderful, when we consider, that different proportions of the same ingredients produce fluids essentially distinct in all

their leading characters. He that "made a weight for the winds, and weigheth the waters by meaſure;" how excellently has he ordered all things for the benefit of his creatures! "The undevout aſtronomer is mad," is the ſtrong expreſſion of a ſublime writer; yet, if the wiſdom and providence of God is evident in thoſe immenſe bodies, of the ſtructure of which we are in a great meaſure ignorant, ſurely it is much more ſo in theſe minute operations, which are the immediate objects of our ſenſes, where every thing is plainly the effect of intelligence and deſign; and, however ignorant and ſuperficial obſervers may wander from the path of truth, the naturaliſt at leaſt can never be an atheiſt.

Book IX.

OF ANIMALS.

Chap. I.

OF ANIMAL MATTER IN GENERAL.

General Remarks on Animal Bodies.—Products from the Distillation of Animal Matter.—Elementary Principles which enter into the Composition of Animal Matter.—Animal Acids.—Different Forms of Animal Matter.—Jelly.—Glue.—Lymph.—Further Products.—Fat.—Fibrous Parts.

IN treating of organized bodies, as introductory to an account of the vegetable system, some observations were made, which are also in a great measure applicable to animal nature. The elementary principles, however, which enter into the composition of animal bodies are more numerous than those which are found in vegetable matter; and at the same time the structure of animals is much more complex than that of plants. In both, the growth and increase is provided for by a curious kind of chemical apparatus, adapted for effecting those wonderful changes, dissolutions, and combinations of matter, which are essential to their respective natures. All, however, that we have been able to discover in vegetables, is some traces of a vascular system; whereas, in animal nature, there is not only a most elaborate system of vessels, but means provided for the augmentation of the temperature, and for the fulfilling of those functions which belong

belong to a creature, endued with a power of voluntary motion, and of thought.

To describe with accuracy the specific characteristics of different animals, to enter into the detail of what is called comparative anatomy, would employ an immense and elaborate treatise; and indeed to acquire the necessary knowledge for such an undertaking would occupy a long life. As the object, however, of the present work is to give a general view of nature, rather than to enter into that minuteness of disquisition which is chiefly necessary for technical purposes, or for those inquirers whose leisure and patience far exceed those of the majority of mankind, it will be necessary to confine the present subject within reasonable limits. And since it would be impossible, in such a work, to treat of the specific organization of every animal, I have made choice of that one, whose parts and functions are found to be the most perfect; and as it is easier to look down from an eminence than to ascend the heights of creation, from what will be stated in the succeeding pages on the economy of the human body, it will not be a matter of great difficulty to comprehend that of other animals *. The plan which will be pursued in this part of the work, will not be materially different from that which has been adopted in the preceding. After a few observations on the component principles of animal matter, I shall proceed to consider the structure of those organs which constitute the animal machine; and lastly, the functions to which those organs are subservient.

* The most striking and characteristic differences in the fabric of different animals are however noticed; but to describe minutely the natural economy of every distinct race of animals, would require an immense treatise, and indeed has never yet been done.

When

When animal matter is diſtilled with a ſtrong heat, we obtain a watery fluid, holding in ſolution ſome ſal ammoniac, ſuperſaturated with volatile alkali; a light oil, and a ponderous dark oil, mixed with concrete volatile alkali; a ſpongy coal remains in the retort, of difficult incineration, and which contains ſea-ſalt, mild foſſile alkali, iron, and calcareous earth, combined with phoſphoric acid.

Such are the products afforded by the diſtillation of all animal matters, except that the proportions vary, according to the degree of ſolidity in the part ſubmitted to diſtillation. The moſt characteriſtic mark of animal matter, is its containing azote, which conſiderably alters its products, both by putrefaction and diſtillation, and which in both theſe proceſſes combining with hydrogen produces volatile alkali. As vegetables and animals, however, paſs by inſenſible degrees into each other, ſo there are ſome vegetables which afford volatile alkali, and which conſequently contain azote; though in far leſs quantity than any animal matter.

The elementary matters which enter into the compoſition of the ſoft parts of animals, are carbon, hydrogen, azote and oxygen; the bones are compoſed of calcareous earth and phoſphoric acid: a very ſmall quantity alſo of iron, and of ſome neutral ſalts, particularly ſuch as are compoſed of the mineral and volatile alkalies, and lime, combined with the muriatic, phoſphoric and carbonic acids, are diſcovered by careful analyſis. By the application of heat, the elementary matters above mentioned aſſume new arrangements and combinations; hydrogen and oxygen uniting, form water; hydrogen and carbon, oil; hydrogen and azote, volatile alkali; oxygen and carbon, cretaceous or carbonic acid: ſome of the gaſſes alſo eſcape in a ſeparate ſtate, and part of the carbon

remains

remains behind with the earthy matter. Lavoisier, after having treated of the decomposition of vegetable matter, observes:

'Animal substances, being composed nearly of the same elements with cruciferous plants, give the same products in distillation, with this difference, that, as they contain a greater quantity of hydrogen and azote, they produce more oil and more ammoniac. I shall only produce one fact, as a proof of the exactness with which this theory explains all the phenomena which occur during the distillation of animal substances—which is the rectification and total decomposition of volatile animal oil, commonly known by the name of Dippel's oil. When these oils are procured by a first distillation in a naked fire, they are brown, from containing a little charcoal almost in a free state; but they become quite colourless by rectification. Even in this state the charcoal in their composition has so slight a connection with the other elements, as to separate by mere exposure to the air. If we put a quantity of this animal oil, well rectified, and consequently clear, limpid, and transparent, into a bell-glass filled with oxygen gas over mercury, in a short time the gas is much diminished, being absorbed by the oil; the oxygen, combining with the hydrogen of the oil, forms water, which sinks to the bottom; at the same time the charcoal which was combined with the hydrogen being set free, manifests itself by rendering the oil black. Hence the only way of preserving these oils colourless and transparent, is by keeping them in bottles perfectly full, and accurately corked, to hinder the contact of air, which always discolours them.

'Successive rectifications of this oil furnish another phenomenon confirming our theory. In each distil-

lation

lation a ſmall quantity of charcoal remains in the retort; and a little water is formed by the union of the oxygen contained in the air of the diſtilling veſſels with the hydrogen of the oil. As this takes place in each ſucceſſive diſtillation, if we make uſe of large veſſels, and a conſiderable degree of heat, we at laſt decompoſe the whole of the oil, and change it entirely into water and charcoal. When we uſe ſmall veſſels, and eſpecially when we employ a ſlow fire, or a degree of heat little above that of boiling water, the total decompoſition of theſe oils, by repeated diſtillation, is greatly more tedious, and more difficultly accompliſhed.'

Animal matters are compound ſalifiable baſes brought to the ſtate of oxyds by combination with oxygen, and which, by the further addition of that principle, are capable of becoming acids. Several animal acids have been diſcovered, ſome of which approach very near to the vegetable acids. Their baſes have not been aſcertained with accuracy, but are ſuppoſed to be different combinations of carbon, hydrogen, and azote. The animal acids at preſent known, are the following:

Lactic acid, obtained from milk.
Saccho-lactic, from ſugar of milk.
Formic, from ants.
Bombic, from ſilk-worms.
Sebacic, from ſuet.
Lithic, from urinary calculus.
Pruſſic, extracted from blood, or other animal matter, by means of fixed alkali ignited with theſe matters.

Having mentioned the principles afforded by the complete decompoſition of animal matter, it will be proper to notice certain matters into which the ſoft parts of animals may be reſolved by the action of

menſtrua.

menſtrua. If a part of an animal is boiled in water, it is gradually diſſolved, and a matter is extracted, which forms a ſolid but tremulous maſs when cold, and which is called jelly. This is found moſt plentifully in the white parts of animals, but may be obtained in a ſmaller or greater proportion from all. It is nearly inodorous and inſipid, and is ſoluble both in cold and hot water, but more eaſily in the latter. When its watery parts are more fully evaporated, it forms glue. The jelly of animals is very analogous to the gum of vegetables, except that the latter does not contain azote, and of courſe is leſs prone to the putrefactive fermentation, and is incapable of affording volatile alkali. The glue obtained by boiling animal matters, differs in ſome meaſure according to the firmneſs or laxity of the ſubſtance from which it is obtained; thus the ſkins, tendons, cartilages, and ligaments afford the firmeſt glue. The ſkins of eels are the baſis of gold ſize; and from old white leather gloves and parchment is made a kind of glue uſed by painters. Glues differ from each other in their conſiſtence, taſte, ſmell, and ſolubility: there are ſome which readily become ſoft in cold water; others are not diſſolved but in boiling water; but the preparation of the latter is not generally known. The beſt glue is tranſparent, of a yellow browniſh colour, without ſmell and taſte, and entirely ſoluble in water, with which it forms a viſcid uniform fluid. Animal jelly differs from glue, only in poſſeſſing a leſs degree of conſiſtence and viſcidity. The firſt is more eſpecially obtained from the ſoft and white parts of animals, and is far more abundant in thoſe which are young. Glue is obtained in greateſt perfection from the tougheſt parts of older animals. Jelly and glue are inſoluble in ſpirit of wine.

Lymph

Lymph or ſerum conſtitutes the greater part of the fluids of animals, and will be afterwards treated of as a conſtituent part of the blood.

Spirit of wine, when applied to animal matters, diſſolves an extractive ſubſtance, which is depoſited on the evaporation of the fluid; this matter is alſo ſoluble in water. It ſwells and liquifies by heat, and emits a ſmell ſomewhat reſembling that of burned ſugar; it is chiefly this ſubſtance which covers the ſurface of roaſted meat, in the form of a brown cruſt.

The fat of animals approaches very nearly to the nature of the fat oils of vegetables. The globules which riſe to the ſurface of water in which meat is boiled, conſiſt of the fat. The fat of animals, as well as the fat oils of vegetables, affords a peculiar acid, which is called the ſebacic acid, or acid of ſuet.

After all theſe matters are extracted, there remains nothing but a white fibrous matter, inſipid, and inſoluble in water. This matter has all the characters of the fibrous part of the blood, which I ſhall treat of in the following chapter.

CHAP. II.

OF THE BLOOD.

Sanguineous and exsanguineous Animals.—Warm and cold blooded Animals.—Serum and Crassamentum.—Polypuses.—Analysis of Blood.—Lymph.—Iron in the Blood.—Cause of the Red Colour.—Red Globules.—Hewson's Experiments.

THIS fluid, which is so essential to life, varies considerably in different species of animals. In man, and other large animals, it is of a red colour, but in some smaller animals the circulating fluid is nearly colourless, and therefore such animals are called exsanguineous; though with little propriety, as their circulating fluid appears to answer all the purposes of blood, and there seems no reason to affirm that nothing can be blood, which is not of a red colour. The most remarkable difference in the blood of animals, is with respect to the temperature. The blood of man, quadrupeds, and birds, is hotter than the medium they inhabit; they are therefore called animals with warm blood. In fishes and reptiles it is nearly of the temperature of the medium they inhabit; and these are therefore called animals with cold blood. The temperature of the blood, as well as the change of colour to a brighter red, which the blood undergoes in passing through the lungs, will be treated of in a future chapter on respiration.

When blood is first drawn from a vein, it appears to be an homogeneous red fluid: it then consolidates into one uniform mass; in a little time a yellowish watery liquor begins to separate from it, which is more

or less in quantity, according to the state of the blood; the red mass, in the mean time, contracts greatly in its dimensions, expelling the watery liquor from its pores, and consequently increasing in firmness and density. This separation happens in the body after death, and produces those concretions in the heart, and large vessels, those adhesive masses called polypuses, which were formerly supposed to have existed during life, and sometimes to have been the immediate occasion of death. By agitation, blood continues fluid; but a consistent fibrous matter adheres to the stick or instrument made use of to stir it, which by repeated ablution in water becomes white, and appears to be very similar to the fibres of animals obtained by washing away the other adhering matters. Received from the vein in warm water, blood deposits a quantity of transparent filamentous matter, the red portion continuing dissolved in the water. On evaporating the fluid, a red substance in the form of powder, or easily reducible to it, is left. Blood inspissated to dryness leaves a dark coloured mass, amounting at a medium to about one fourth part of its weight, of a bitter saline taste, easily inflammable, and burning with a blueish flame. The exsiccated blood is not soluble in acid or alkaline liquors, but gives some tinge to water and to spirits of wine; and is more powerfully acted on by dulcified spirit of nitre. Recent blood is coagulated by the mineral acids, and by most of the combinations of them with earthy and metallic bodies. With vegetable acids, and with solutions of neutral salts, it mingles equally without coagulation. Alkalies, both fixed and volatile, render it more fluid, and preserve it from coagulating. Blood by distillation affords the same results as other animal matters. Six pounds of human blood distilled to dryness, with a gentle heat, were reduced

duced to a pound and an half; after which the mafs was urged with a graduated fire, till the retort at laſt became red hot. The produce was ſeventeen ounces of liquor, twelve of which were a red and very empyreumatic volatile and alkaline fluid, and the other five were oil. What remained in the retort was a light coal, weighing four ounces and a half.

It has been already mentioned that blood ſpontaneouſly ſeparates into two parts, a coherent mafs called the craſſamentum, and an aqueous liquor called the ſerum, with which the craſſamentum is ſurrounded.

Lymph or ſerum, which is alſo called the albuminous matter, from its coagulating into a white mafs by the application of a heat equal to 156 degrees of Farenheit's thermometer, is very analogous to the white of egg. Serum is alſo coagulated by acids and by ardent ſpirit; alkalies render it more fluid. It converts ſyrup of violets to a green. Its colour is yellowiſh, inclining to green; its taſte is ſaline, and it feels between the fingers in ſome degree unctuous and adheſive. By diſtillation it affords the ſame principles as animal matters in general.

Serum, expoſed to a warm temperature in the open air paſſes quickly to putrefaction. It unites with water in all proportions, but they are kept ſeparate by their different denſities, unleſs agitated together. Serum poured into boiling water for the moſt part coagulates inſtantly. The coagulation formed in ſerum by the addition of an acid, diſſolves very quickly in volatile alkali, which is the true ſolvent of the albuminous part; but it is not at all ſoluble in pure water. The coagulation formed by ſpirit of wine, on the contrary, is ſoluble in water, as M. Bucquet has diſcovered. This liquid, M. Fourcroy concludes, is an animal mucilage, compoſed of water, acidifiable oily baſes,

marine ſalt, chalk of ſoda, and calcareous phoſphat; this laſt appears to produce the roſe-coloured precipitate, obtained by pouring the nitrous ſolution of mercury into ſerum. Though the liquid is ſcarcely coloured, the addition of nitrous acid, and more eſpecially of mercurial nitre, produces a roſe or light fleſh-colour, which M. Fourcroy has often obſerved in many other animal liquors.

The craſſamentum, when well waſhed in water, is ſeparated into two very diſtinct ſubſtances, one of which is diſſolved, and tinges the water of a red colour, while the other remains behind in the ſtate of a white fibrous matter, the ſame as that which adheres to the ſtirrer with which recent blood has been agitated, in order to prevent its coagulation. The water in which the red part is diſſolved, when heated with different menſtrua, exhibits all the characters of ſerum; but it contains a much greater quantity of iron, which may be obtained by the incineration of the coal, and ſubſequent waſhing to ſeparate the ſaline matters. The reſidue of this waſhing is a yellow calx of iron, of a beautiful colour, and uſually attracted by the magnet. The red colour of the blood is therefore with ſome appearance of reaſon attributed to this metal. Iron has been obtained from the blood in conſiderable quantity by Menghini, Rouelle, and Bucquet.

The ſame chemiſts found that iron was capable of paſſing into the blood from the inteſtines, ſince patients who were under a courſe of martial medicines are known to diſcharge a part of it by the urinary paſſages. Iron is obtained from the red particles of the blood, but not from the waſhed coagulum. Theſe facts, together with the increaſed redneſs of the blood by paſſing through the lungs, where it may be ſuppoſed to ſuffer a degree of calcination from the abſorption

of oxygen, render the above opinion highly probable.

The fibrous part of the blood, when thoroughly washed, is white and insipid; by distillation, like other animal matters, it affords water, oil and volatile alkali. Exposed to a gentle heat, it is much hardened; when suddenly exposed to a strong heat, it shrinks up like parchment. It putrefies very rapidly, and affords much volatile alkali. It is insoluble in water, and when boiled in that fluid hardens, and assumes a grey colour. Acids unite with it, and in particular the nitrous acid dissolves it, and extricates azote and nitrous air; while the residue by evaporation affords acid of sugar in crystals, a peculiar oil in flocks, and the phosphoric salt of lime. Marine acid forms a green jelly with the fibrous part of the blood. The acid of vinegar dissolves it with the assistance of heat; water, and more particularly alkalis, precipitate the fibrous matter when dissolved in acids. The animal substance is decomposed in these combinations; and when separated from the acids by any method, it no longer retains its former properties.

The microscopical appearances of the blood have attracted great attention. Various accounts have been published on this subject, most of which seem to have been framed more on theory and pre-conceived opinion, than actual observation. These falsities have been detected by Mr. Hewson, whose microscopical experiments on the blood are the latest which have been made, and remain at present (as far as relates to the composition of the blood) uncontradicted. I shall therefore transcribe the following particular account of them, given by himself in a letter to Dr. Haygarth, physician, in Chester.

'The red particles of the blood, improperly called *globules*, are flat in all animals, and of very different fizes in different animals. In man they are fmall, as flat as a fhilling, and appear to have a dark fpot in the middle. In order to fee them diftinctly, I dilute the blood with frefh ferum. My predeceffors, not having thought of this, could not fee them diftinctly. And Lewenhoeck in particular, imagining a round figure fitteft for motion, concluded they muft be round in the human body; though he and others allowed that in frogs, &c. where they viewed them diftinctly, from the blood being thinner, they were flat. Now I prove that they are flat in all animals. In the human blood, where thefe particles are fmall, it is difficult to determine what that black fpot is, which appears in the center of each. Some have concluded that it was a perforation; but in a frog, where it is fix times as large as in a man, it is eafy to fhew that it is not a perforation, but on the contrary, is a little folid, which is contained in the middle of a veficle. Inftead, therefore, of calling this part of the blood red *globules*, I fhould call it red *veficles*; for each particle is a flat veficle, with a little folid fphere in the center.

'I find that the blood of all animals contains veficles of this fort. In human blood there are millions of them, and they give it the red colour; but in infects they are white, and lefs numerous in proportion than in man and quadrupeds. As they are flat in all animals, I fufpect that fhape is a circumftance of importance, but can be altered by a mixture with different fluids. And I find, that it is by a determinate quantity of neutral falt contained in the ferum, that this fluid is adapted to preferving thefe veficles in their flat fhape: for if they are mixed with water, they become round, and diffolve perfectly; but add a little of any neutral

neutral ſalt to the water, and they remain in it without any alteration in their ſhape, and without diſſolving.

‘ Now, when it is conſidered that the blood of all animals is filled with theſe particles, we muſt believe that they ſerve ſome very important purpoſe in the animal œconomy; and ſince they are ſo complicated in their ſtructure, it is improbable that they ſhould be formed by mechanical agitation in the lungs or blood-veſſels, as has been ſuſpected, but probably have ſome organs ſet apart for their formation. This I ſhall endeavour to prove, when I have explained their ſtructure a little more particularly, and mentioned the manner in which I exhibit it. I take the blood of a toad or frog, in which they are very large; I mix it with the ſerum of human blood to dilute it; I find them appear all flat, ſo they do in the blood-veſſels of this animal, as I have diſtinctly ſeen in the web between its toes, whilſt the animal was alive, and fixed in the microſcope. Their appearance in theſe animals is not unlike ſlices of cucumber. I next mix a little of the blood with water, which immediately makes them all round, and then begins to diſſolve them whilſt they are round. I incline the ſtage of the microſcope, ſo as to make them roll down it; and then I can diſtinctly ſee the ſolid in the middle fall from ſide to ſide, like a pea in a bladder. A neutral ſalt added to them at this time brings them back to their flat ſhape; but if the ſalt is not added, the water gradually diſſolves away the veſicle, and then the little ſphere is left naked. Such is the compoſition of theſe particles. I have exhibited theſe experiments to a conſiderable number of my acquaintance, who all agree in their being ſatisfactory.

‘ The microſcope I uſe is a ſingle lens, and therefore as little likely to deceive us as a pair of ſpectacles,

which, as is allowed by all who uſe them, do not diſfigure objects, but only repreſent them larger.'

It is unneceſſary to follow Mr. Hewſon into his ſpeculations with regard to the uſe of the thymus and lymphatic glands, which he thinks are deſigned to fabricate the middle ſolid particles of the blood which are afterwards to be furniſhed with veſicles in the cells of the ſpleen. Theſe inquiries may ſhew the ingenuity of their author, but will not anſwer our purpoſe, which is to detail with conciſeneſs what has been aſcertained with certainty.

CHAP. III.

STRUCTURE OF ANIMALS.

Size of Man.—His erect Posture.—Varieties in the Structure of Animals.—Parts of the Animal Body.

IN taking a general view of the formation of MAN, a circumstance of importance is his size, considered in relation to the force of gravitation. If the size of man was much greater than it is, supposing his strength to be only in proportion, his motions would be much slower, and more laborious; nor would his increase of size be entirely compensated by a diminution in the force of gravitation, for this would expose him to inconveniences, on account of the various relations in which he stands to other objects. On the contrary, was man much smaller, though he would gain in celerity what he would lose in force, yet his weakness would incapacitate him for acting with advantage on considerable masses of matter. On the whole, it should seem, that neither an increase of size with an increase of gravitation; nor a diminution of size with a diminution of gravitation; nor an increase of either with a diminution of the other, would in general so well suit the conveniences of man, and his relation to other beings, as the state in which he at present subsists.

The most striking difference of structure between man and the other animals is his erect figure, excellently adapted to the more extensive views which he

was

was designed to take of nature; and which, instead of being a mark, as a French writer pretends to think, of human arrogance, in departing from the horizontal posture, which was allotted to man in common with other quadrupeds, is one proof of the distance which the Deity meant to interpose between him and the rest of the animal creation. That author, however, denies the superiority of man in every respect; and maintains, that the mental acquirements of a horse would not be inferior to those of a man, if the former was furnished with fingers, and endued with the same exquisite sense of feeling which the latter enjoys. We may grant that all our simple ideas are derived from the information of our senses; but we would ask what experiments this philosopher or his adherents have made, to ascertain, that there can be no differences in the structure of intellectual organs? and upon what authority they conclude, that all the varieties we observe in mental endowments, among individuals of the same race, as well as among different races of animals, are solely to be referred to differences in the organs of sense? But granting all that he requests, how came man to have fingers and horses none, if they were equally designed to gallop through the forest? —he must either have made fingers for himself, or he must have been originally designed by his Maker for nobler occupations.

The structure of man, moreover, in several other particulars, entirely confutes the assertions of this contemptible visionary; but without attending to other circumstances, it will be sufficient to mention the formation of the lower extremities in man, so different from the hind legs of quadrupeds, and so admirably adapted to the erect posture. By some naturalists the Ourang-Outang is considered as the original stock of the human race.

race. His claims to humanity are founded upon his being able to walk upright, being furniſhed with ſuch muſcles as are requiſite for that purpoſe. The form of his heart, lungs, breaſt, brains, and inteſtines are ſimilar to thoſe of a man. He can ſit upright with eaſe, and can handle a ſtick with dexterity. That his race is diſtinct, however, from that of man, is evident from his having thirteen ribs on each ſide, whereas man has but twelve. He has not the faculty of ſpeech, and articulation is impoſſible to him, on account of the ſtructure of the parts about the larynx.

While, however, we diſſent from theſe authors, in ſinking man to the level of other animals, let us reflect that the purpoſe of nature ſeems to be, to diffuſe life and enjoyment wherever they can exiſt; and let us avoid the oppoſite, narrow-minded, and, if poſſible, ſtill more abſurd notion, that the happineſs of man is the ſole object of creation.

In the animals which more commonly fall under our obſervation, the ſurface is ſoft, and the bones are deeply ſeated; but in others the reverſe happens, and we obſerve the bones forming a caſe to the ſofter parts. We ſee ſome animals furniſhed with wings, to ſport in the regions of the atmoſphere; ſome immerſed by means of a heavy ſhell, during the whole of their exiſtence, in the depths of the ocean; and others furniſhed with organs, to perforate their dark paſſage through the bowels of the earth. In general the bones of animals are filled with marrow, but in many kinds of birds they are excavated for the reception of air, fitting them for floating more eaſily on the ſurface of water, and at the ſame time, when neceſſity requires, for remaining longer beneath its ſurface. In ſome animals, even the brain and heart eſcape our moſt careful reſearches; and ſome, like vegetables, may be multiplied from the

the limbs of their parents. So endlefs indeed are thefe differences, that there is perhaps no one circumftance of ftructure or function common to all animals.—— But let us return from thefe extenfive profpects to the confideration of the ftructure of our own fpecies.

Before we proceed, however, to confider the ftructure of the body, it will be proper to premife a few very brief definitions of the moft remarkable parts of which it confifts.

Bones are hard fubftances, which form the bafis of the body.

Cartilages are firm, fmooth, elaftic bodies, which cover the ends of the bones.

Mufcles are contractile organs, which are attached to bones, and perform the motions of the body.

Tendons are tough cords, by means of which mufcles are attached to bones.

Ligaments are ftrong fibres or membranes, which connect bones to each other.

Blood-veffels are membranous flexible tubes, which convey the blood to and from the heart.

Lymphatics are tranfparent tubes, which perform abforption.

Nerves are white cords connected with the brain, and are the inftruments of fenfation and voluntary motion.

Glands are organic maffes, deftined for the purpofe of fecretion.

CHAP. IV.

STRUCTURE OF THE BONES.

Bones consist of Fibres; cellular.—The Marrow.—Waste of Bone in old Age.—Epiphyses.—Periosteum.—Progress of Ossification.—Articulation.

THE body, as Hippocrates long ago remarked, is a circle; and therefore at whatever point we were to begin the description, we should ultimately be equally led, by the connexion of parts, to the consideration of the whole. Since the bones, however, may be considered as the basis of the body, on which the other parts depend for situation and support, it appears most eligible in the first place to consider their structure and uses.

The bones consist of fibres, distributed in lamellæ or plates; these plates are not closely applied to each other, but, with the intervention of transverse fibres, constitute cells. The cells are distributed through the substance of all the bones, but are uniformly most remarkable in the center, and on the surface of the harder bones are so small as not to be distinctly perceptible without the aid of glasses.

The marrow which fills the cavities of the bones is a fat oily substance, contained in a fine and transparent membrane, which receives numerous blood-vessels, and is supported by the filaments of the reticular substance of the bones. If the different parts of a bone are observed, it is found that where the diameter of the bone is the least, there the sides are thickest and most compact; where the diameter is greatest, which

which is in general towards the ends of the long bones, their ſtructure is very cavernous throughout. The marrow pervades the whole ſubſtance of the bones, but is moſt remarkable in the middle part of the cavities of the long bones. Its appearance and nature alſo differ in different bones, or in the ſame bone in the progreſs of life. Thus the marrow is bloody in children, oily in adults, and thinner and more watery in aged people.

At the time of birth, the bones are very imperfect, particularly thoſe of the head; ſo that by being moveable in this part, and folding over each other during the time of delivery, an eaſier paſſage is procured for the infant. There are many projections from the bones, which in infancy are ſoft, but which in the adult ſtate are bony; and the ſame tendency to the formation of bone increaſing with our years, bones which were ſeparate in the prime of life concrete in old age. In the decay of the body, however, the bones are diminiſhed with the other parts, ſo as in extreme old age to weigh a third leſs than in the middle periods of life.

To far the greater number of bones whoſe ends are not joined to other bones by immoveable articulation, are annexed, by the intervention of cartilage, ſmaller bones, called epiphyſes or appendages. In young ſubjects theſe are eaſily ſeparable, but in adults the point of conjunction is not very perceptible.

The bones are furniſhed with a tough membrane, called the perioſteum, which is ſpread on their ſurface, and the principal uſe of which ſeems to be to convey blood-veſſels for their nouriſhment; theſe blood-veſſels are very numerous and remarkable in the bones in the infant ſtate, but become gradually leſs ſo in the progreſs of life.

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It has been ſuppoſed that the bones were formed by the ſucceſſive oſſification of layers of the perioſteum. This opinion, however, is contrary to what is obſerved on examining bones in the progreſs of their formation: and is alſo diſproved by ſome experiments, in which animals were fed with madder. Their bones were found to be tinged in proportion to the length of time that they were kept on this food; but neither the perioſteum nor the cartilages were altered from their natural colour.

The moſt general diviſion of the bones is that into the long and cylindrical, and the flat and the broad. The oſſification in both theſe kinds of bones begins in the middle, at ſeveral points at a time, and gradually extends towards the ends of the long bones and the circumference of the broad.

The ends of the long bones, where they are united to each other, are larger than their middle part, and ſeveral advantages attend this ſtructure. By theſe means the ſurface of contact between the two bones of an articulation is increaſed, their conjunction conſequently becomes firmer, there is more ſpace for the connection of muſcles, which alſo act more powerfully from their axes being further removed from the middle of the joint, or the center of motion.

The bones are united to each other, either moveably or immoveably. They are moveably articulated in three ways:—1ſt. By a ball and ſocket, which admits of motion in all directions, as in the ſhoulder. 2dly, By a hinge, which allows motion in only two directions, as in the knee; and 3dly, By a long proceſs of one bone received into the cavity of another, which admits of a rotatory motion, as in the articulation of the firſt and ſecond vertebræ of the neck. The immoveable articulation of bones is of two kinds: 1ſt, where numerous

merous proceffes of two bones, like the teeth of faws, are mutually received into each other, as in the bones of the head; and 2dly, by the growing together of bones with the intervention of cartilage, as in the union of the os facrum with the offa innominata.

The ends of bones which move on each other are tipped with fmooth cartilage; and the friction is ftill further diminifhed by a fluid, much more flippery than oil itfelf, which is called the fynovia. The moveable joints are alfo furnifhed with ftrong membranes, called ligaments, which pafs from one bone to another, affording ftrength, and retaining the heads of the bones in their cavities. For the purpofes of articulation, and the connection of mufcles, bones are uneven on their furface, and have numerous elevations and depreffions.

CHAP. V.

DIVISION OF THE SKELETON, WITH THE BONES OF THE HEAD.

The Skeleton briefly deſcribed.—Bones of the Cranium.—Bones of the Face—of the Noſe—of the Palate.—The Upper and Under Jaw.—Form and Proportion of the Head.—Subſtance and Structure of the Bones of the Head.—Sutures.

THE ſkeleton, by which is underſtood all the bones of the body in their proper ſituations, is divided into the head, trunk, and extremities.

When the bones are put into a natural ſituation, ſcarcely any one of them will be found to have a perpendicular bearing on another; though the fabric compoſed of them is ſo contrived, that in an erect poſture a perpendicular line from the common centre of gravity falls in the middle of their common baſe. On this account, we can ſupport ourſelves as firmly, as if the axis of all the bones had been a ſtrait line, perpendicular to the horizon; and we have much greater quickneſs, eaſe, and ſtrength, in ſeveral of the neceſſary motions, as well as other advantages in the ſituation and protection of the viſcera. It is true, indeed, that wherever the bones on which any part of the body is ſuſtained, decline from a ſtrait line, the force of the muſcles required to counteract the gravity is greater than would be otherwiſe neceſſary; but this is more than compenſated by the advantages above mentioned.

The bones of the head are divided into thoſe of the cranium and face. The cranium, or that bony caſe which ſurrounds and protects the brain, conſiſts of

 eight

eight pieces of bone. At the fore part is placed the os frontis; at the back part the os occipitis; at the upper and ſide parts the oſſa parietalia; at the under and ſide parts, the oſſa temporalia; in the fore part of the baſe the os ethmoides; in the middle of it the os ſphenoides. Theſe two latter bones are common to the cranium and face.

The os frontis is ſo called from being the only bone of the forehead, though it extends conſiderably farther upwards. It has ſome reſemblance in ſhape to the concha bivalvis, commonly called the cockle. The greater part of it is convex externally, and concave internally, with a ſerrated circular edge. The upper part of the os frontis, where it is connected to the parietal bones, is very ſmooth and convex, but below it has ſeveral inequalities, where it contributes conſiderably to the formation of the cavities, in which the eyes are lodged. In the part of the os frontis which correſponds with that part of the forehead immediately above the eye-brows, the two tables of the bone ſeparate by the external being protruded outwards, to form two large cavities, called frontal ſinuſes. Theſe cavities communicate with the external air by means of the noſe. The frontal bone ſerves to ſupport and protect the anteri r lobes of the brain. The falx of the dura mater, of which I ſhall have occaſion to ſpeak more fully hereafter, is attached to a ridge or furrow at the middle and internal part of this bone. The os frontis is pierced with ſome ſmall holes for the paſſage of blood-veſſels.

Each of the two oſſa parietalia is an irregular ſquare, its upper and fore ſides being longer than that behind or below. The inferior ſide is a concave arch; the middle of it receiving the upper and round part of the temporal bone. The external ſurface of each parietal

bone

bone is convex. On their inner concave ſurface we obſerve a number of deep furrows, diſpoſed like the branches of trees, which receive the blood-veſſels of the dura mater. On the inſide of the upper edge of the oſſa parietalia, there is a large ſinuoſity, where the upper part of the falx is faſtened, and the ſuperior longitudinal ſinus is lodged. The oſſa parietalia are the moſt equal and ſmooth, and are among the thinneſt bones of the cranium; and yet the diviſion of their ſubſtance into two tables and a diploe is no where ſo remarkable. Theſe bones are joined before to the os frontis by the coronal future; at their long inferior angles, to the ſphenoid bone, by part of the future of this name; at their lower-edge, to the oſſa temporum, by the ſquamous future; behind to the os occipitis, by the lambdoidal future; and above to one another, by the ſagittal future. In a child born at the full time, none of the ſides of this bone are completed, and the brain is in general not completely ſurrounded by a bony caſe, till ſix or ſeven years of age.

The oſſa temporum are equal and ſmooth above, where they terminate in a thin ſemicircular edge, which is laid over the inferior part of each of the oſſa parietalia, as the ſcales of fiſh are placed over each other, forming a juncture, which is on this account called ſquamous. Behind this, the upper part of the temporal bone is thicker, and more unequal. Towards the baſe of the ſkull, the temporal bone is very irregular and unequal, and becomes contracted into an oblong very hard ſubſtance; and being extended forwards and inwards, becomes ſmaller, and is called the os petroſum, which contains the internal parts of the organ of hearing. This bone has three remarkable proceſſes. The firſt placed at the lower and poſterior part of the bone, is from its reſemblance to a nipple called maſ-

toides or mamillaris. Within it is compoſed of ſmall cells, which have a communication with the organs of hearing. About an inch farther forward, the ſecond proceſs begins to riſe from the bone; and having its origin continued obliquely downwards and forwards, it becomes ſmaller, and is at length united with a correſponding proceſs of the os malæ, or cheek-bone. In this manner is formed a bony jugum or yoke, under which the temporal muſcle paſſes. Hence this proceſs of the temporal bone has been called zigomatic. From the inferior unequal part of the os temporum the third proceſs ſtands out obliquely forwards; the ſhape of it has been thought to reſemble the ancient ſtylus ſcriptorius, and it is therefore called the ſtyloid proceſs, The chief uſe of theſe proceſſes is to afford attachment to muſcles. Numerous ſinuoſities or depreſſions of this bone, by increaſing the ſurface, anſwer the ſame purpoſe. This bone has alſo ſeveral perforations, one of which, ſituated between the zigomatic and maſtoid proceſſes, is the orifice of a large funnel or canal, which leads to the organ of hearing.

The os occipitis, ſo called from its ſituation at the back part of the head, like the other bones of the cranium, is externally convex, and internally concave. Its figure is an irregular ſquare, or rather a rhomboid; of which the angle above is generally a little rounded; and the lower angle is extended to the inferior part of the cranium, in the form of a wedge, and is thence called the cuneiform proceſs. At the baſe of this triangular proceſs, on each ſide of the great foramen, through which paſſes the ſpinal marrow, are obſerved two large oblong proceſſes, called the condyles, which ſerve for the articulation of the cranium with the firſt vertebra of the neck. Around the great foramen, the edges are unequal, for the firmer adheſion of the ſtrong circular

cular ligament which paſſes from the circumference of the foramen to the firſt vertebra. On the inſide of the occipital bone are ſeveral ridges and furrows; to one of the ridges is fixed the poſterior part of the falx, and the furrows receive the ſinuſes which run in this part of the cranium. The ridges of this bone form a croſs, and round the middle of the croſs there are four large depreſſions, ſeparated by its limbs; the two upper depreſſions being formed by the poſterior part of the brain, and the two lower by the cerebellum. The inner ſurface of the cuneiform proceſs is hollowed for the reception of the medulla oblongata and the baſilar artery. Beſides the great foramen, there are ſeveral other perforations in this bone, or between it and the adjoining bones, for the paſſage of nerves and blood-veſſels. The occipital bone at its upper part, where it is chiefly expoſed to injury, is very thick and ſtrong, but lower down, where it is protected by the ſtrong and thick muſcles which are inſerted into it, it is often very thin. The occipital bone is connected above to the oſſa parietalia by the lambdoidal ſuture; laterally to the temporal bones by a continuation of the ſame ſuture; below it is firmly connected by an union of ſubſtance to the ſphenoid bone, by means of the cuneiform proceſs.

The os ethmoides, or ſieve-like bone, derives its name from the numerous ſmall apertures with which it is pierced at its fore part. From the middle of the internal ſide of the lamella, which is ſo full of holes, a thick proceſs riſes upwards; and being higheſt at the fore part, gradually becomes lower as it is extended backwards. From a fancied reſemblance of this proceſs to a cock's comb, it has been called the criſta-galli. The falx is connected to its ridge, and to the unperforated part of the cribriform plate. All the pro-

 minences,

minences, cavities, and meanders of the ethmoid bone are covered with a continuation of the membrane of the noſtrils. The uſes of this bone are to ſuſtain the anterior lobes of the brain; to give paſſage to the olfactory nerves, and attachment to the falx; to enlarge the organ of ſmelling, by allowing the membrane of the noſe a greater extent; to form a part of the orbit of the eyes, and the ſeptum varium.

The os ſphenoides, or wedge-like bone, which is ſo called from its ſituation in the middle of the bones of the cranium and face, is of a very irregular figure, and bears ſome reſemblance to a bat, with its wings extended. This bone is generally divided into a body, and two ſides or wings. When we view the external part of the os ſphenoides, two or three remarkable proceſſes from each ſide of it may be obſerved, which are all of them again ſubdivided. The firſt pair conſiſts of the two large lateral proceſſes or wings; the upper part of each of which is called the temporal proceſs, becauſe they join with the temporal bones in forming the temples: that part of the wings which projects towards the inſide, ſomewhat lower than the temporal proceſſes, and is ſmooth and hollowed, forms part of the orbits. The loweſt and back part of each wing runs out with a ſharp point, called the ſpinous proceſs, to meet the point of the pars petroſa of the temporal bone. The ſecond pair of external proceſſes of the ſphenoid bone are the aliform or pterygoid, and which ſtand out almoſt perpendicular to the baſe of the ſkull. Each of them has two plates and a middle foſſa at the poſterior ſurface. Of theſe plates, the exterior is the broadeſt; the interior are longeſt, and terminate in a hook-like proceſs. Another pair of proceſſes may be mentioned, viz. the little triangular thin proceſſes which come from each ſide of the ſphenoid bone, where the

pterygoid

pterygoid proceſſes riſe from it; theſe are extended to join the ethmoid bone. The external ſurface of this bone is every where covered with depreſſions, ſinuoſities, and foſſæ. Within there are three remarkable foſſæ; two of theſe are ſeated in the internal part of each wing of the ſphenoid bone, for receiving the middle part of the brain. The third, which is ſmaller, is ſeated on the top of the body of the bone, which from its reſemblance to a Turkiſh ſaddle is deſcribed under the name of ſella turcica. In this foſſa a gland called the pituitary is placed; behind and before it are the clinoid proceſſes. The holes on each ſide of the os ſphenoides are ſix proper and three common. The firſt is a round aperture, immediately below the anterior clinoid proceſſes, which tranſmits the optic nerve and ocular artery. The ſecond, which is a large ſlit, and is called the foramen lacerum, tranſmits the third, fourth, ſixth, and the firſt branch of the fifth pair of nerves. The third hole, ſituated a little lower, is called rotundum from its ſhape, and tranſmits the ſecond branch of the fifth pair of nerves. The fourth is the foramen ovale, about half an inch behind the foramen rotundum; through it paſſes the third branch of the fifth pair. Very near the point of the ſpinous proceſs is the fifth hole of this bone, which is ſmall and round, and gives paſſage to the largeſt artery of the dura mater. The ſixth proper hole cannot well be ſeen till the cuneiform bone is removed from the other bones of the cranium—for one end of it is hid by a ſmall protuberance of the internal plate of the pterygoid proceſs, and by the point of the proceſſus petroſus of the temporal bone. Through it a conſiderable branch of the fifth pair of nerves is reflected. The firſt of the common apertures is that unequal fiſſure at the ſide of the ſella turcica, between the extreme point of the os pe-

trofum and the fpinous procefs of the cuneiform bone. This perforation only appears after the bones are boiled; for in a recent fubject, its back part is covered by a thin bony plate, which lies over the internal carotid artery, and farther forward it is filled with a cartilaginous ligament, under which the cartilaginous part of the euftachian tube is placed: it was by this paffage that the ancients believed the flimy matter was conveyed from the glandula pituitaria to the fauces. The fecond aperture is a large difcontinuation of the external fide of the orbit, left between the orbitar proceffes of the fphenoid bone, the os maxillare, malæ, and palati. The third common aperture is formed between the bafe of this bone and the root of the orbitar procefs of the palate bone of each fide.

Under the fella turcica, within the fubftance of the fphenoid bone, are two finufes, feparated by a bony plate, which are lined with a membrane, and open into the noftrils.

The fphenoid bone is joined to all the bones of the cranium, and likewife to the offa maxillaria, offa malorum, offa palati, and vomer.

The face is divided into the upper and under maxillæ or jaws. The upper jaw is the immoveable part of the face, which confifts of fix bones on each fide, and a thirteenth in the middle. The thirteen bones are, two offa nafi, two offa unguis, two offa malarum, two offa maxillaria, two offa palati, two offa fpongiofa inferiora, and the vomer. The offa nafi are placed at the upper part of the nofe; the offa unguis are the internal canthi of the orbits; the offa malarum form the prominence of the cheeks; the offa maxillaria form the fide of the nofe, with the whole lower and fore part of the upper jaw, and the greateft part of the roof of the mouth; the offa palati are

fituated

ſituated at the back part of the palate, noſtrils, and orbit; the oſſa ſpongioſa are ſeen in the lower part of the noſtrils; and the vomer helps to ſeparate theſe two cavities. The bones of the face, beſides being connected to the bones of the cranium by ſutures, common to them with the bones of the cranium, are joined to each other by fifteen ſutures, which it would be tedious to deſcribe. Neither does a deſcription of the form and connection of each of theſe ſmall bones fall in with the general view of the ſtructure of the body which I propoſe to take,

The lower jaw in the adult conſiſts of only one bone. In form it reſembles a horſe-ſhoe, the convex part of which is turned forwards, and forms the chin. At its back part this bone is bent upwards, and terminates in two proceſſes. The anterior of theſe, which riſes higheſt, is a thin point, into which muſcles are inſerted. The poſterior proceſs terminates in an oblong ſmooth head tipped with cartilage; it is called the condyloid, and is received into a foſſa of the temporal bone, where it is capable of very extenſive motion. There is a cavity through the ſubſtance of this bone, which receives a large twigg of the third branch of the fifth pair of nerves. This begins at the bottom of each coronoid proceſs, and terminates externally near the chin. This bone is furniſhed with an outer and inner bony plate, called the alveolar proceſſes, for retaining the teeth with firmneſs. In each of the jaws are placed ſixteen teeth; ſo that the head, if we include the os hyoides, a ſmall bone ſituated under the chin, conſiſts in the adult of ſixty-three pieces,

With reſpect to the form of the cranium, when ſeen from above, and when the forehead is placed next the eye, it very much reſembles that of an egg, the os frontis correſponding to the ſmaller end of it, and the

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os occipitis to the greater. When seen in any other point of view, however, this resemblance is not perceptible. The sides of the head are flat, and the lower part is flat and irregular. The bones of the face constitute an imperfect triangle. The size of the head, in a well-formed person, is to the rest of the body as one to nine.

The substance of the bones of the cranium is in general made up of two tables or plates, with the interposition of a spongy cavity. The external table is thicker, smoother, and covered with the periosteum; the internal is thinner, more uneven, more brittle, and is lined with a thick vascular membrane, called the dura mater.

The bones of the head are united to each other by a number of tooth-like processes; and these joinings are called sutures. The coronal suture runs across the head, and connects the frontal bone to the parietal bones. The sagittal suture divides the upper part of the head into two equal parts. It connects the two parietal bones to each other, and passes from the middle of the frontal to the middle of the occipital bone.

The lambdoid suture is interposed between the back and fore parts of the cranium, or between the occipital and two parietal bones. The two squamose sutures connect the temporal bones to the parietal. There are also many less remarkable sutures, which join the bones of the face to those of the cranium.

CHAP. VI.

THE TEETH.

General Description of the Teeth.—Incisores.—Canini.—Molares.—Enamel of the Teeth.—Growth of the Teeth.—The Face lengthened after Eight Years of Age.—Varieties in the Teeth of different Animals.

THE teeth, both of the upper and lower jaw, are fixed in ſockets of the jaw-bones, formed of thin bony lamellæ. That part of the teeth which projects beyond the gums, is called their body; the external termination of the body, the corona or crown; and that which is hid, and which terminates in a wedge-like point, is called the radix or root. The roots of the teeth are perforated at their extremities, for the reception of nerves and blood-veſſels.

The teeth are divided into three orders. The four front cutting teeth, are called inciſores. Next to theſe is placed on each ſide a tooth, called from its form the canine or dog-tooth; and laſtly, on each ſide five molares or grinding teeth. The laſt tooth on each ſide, from its not being cut till after the age of puberty, is alſo called dens ſapientiæ, or the tooth of wiſdom.

The four inciſores are ſmaller and narrower in the lower than in the upper jaw. The corona of the inciſores is broad and ſharp, and in children is much notched. The roots of the inciſores are ſhort, and terminate in a ſingle blunt apex. The canine teeth are ſtronger, more acute, and more deeply rooted than the inciſores. They are convex before and concave behind, and are fitted for tearing our food to pieces. The molares, by the eminences on the corona, and by their broad upper ſurfaces, are evidently, as their name expreſſes, deſigned

ſigned for the grinding of the food. The anterior molares are ſmaller and leſs uneven on the corona than the poſterior; the ſtrongeſt being placed neareſt the articulation of the jaw-bone, becauſe there we can exert the greateſt force. The roots of the molares are long and pointed; each tooth has two, three, four, and ſometimes, though very rarely, five roots. The roots ſometimes ſtand ſeparate, ſometimes are concreted together; ſometimes they are ſtrait, ſometimes crooked.

The ſubſtance of the teeth is compact. The corona is covered with a curious ſubſtance, called the enamel. This is thin, white, ſhining, and, being the hardeſt and moſt compact ſubſtance in the body, is admirably adapted to the purpoſes of maſtication.

It is ſcarcely neceſſary to remark, that in eating we only move the lower jaw, and that the upper is on all occaſions fixed and immoveable,

In the infant ſtate, two ſets of teeth are already obſervable in the jaw-bones. In the cutting of the teeth, the inciſores firſt make their appearance, in general about the eighth month; and afterwards, at about two years of age, two molares and the dog-tooth. The firſt ſet of teeth when complete is but twenty in number, viz. eight inciſores, eight molares, and four canini. In the ſecond ſet are added twelve molares, viz. three on each ſide in each jaw, making the complete ſet in the adult thirty-two. To make room for this addition, the jaws undergo a gradual elongation. Hence the face is ſo much lengthened from eight to eighteen years of age. About the ſeventh year the ſecond ſet begins to ſupply the place of the firſt, which by this time become looſe, by the waſte of the ſockets and the growth of the teeth below.

If we extend our views to the lower animals, we ſhall find no part of the body more various among different

different races than the teeth. This circumſtance is ſo remarkable, that Linnæus has employed it in the diſtribution of the firſt claſs of animals (the mammalia) into its ſeveral orders. To enumerate all the varieties of teeth would be impoſſible, and at preſent it would be ſuperfluous. Let it be remarked, however, that they are not without their uſes, and that every animal experiences the advantages of its own peculiar ſtructure.

Chap. VII.

BONES OF THE TRUNK.

Spine or Back Bone.—How the Head is moved.—The Thorax.—The Pelvis.—Principal Marks of Distinction between the Male and Female Skeleton.

THE bones of the trunk are divided into thofe of the fpine or back-bone, the thorax or cheft, and the pelvis. The fpine confifts of twenty-four pieces of bone called the vertebræ; feven of thefe belong to the neck, twelve to the back, and five to the loins. The thorax confifts anteriorly and latterly of twelve ribs on each fide of the fternum or breaft-bone, and part of the fpine behind. The pelvis is compofed of four bones; two offa innominata or hip-bones; the os facrum, and the os coccygis.

That feries of bones called the fpine forms a column larger below than above, fmooth and round before, very rough and uneven behind, and hollow within. The bones of the fpine are joined to each other by cartilages, in the centre of each of which is contained a fluid; a curious circumftance of ftructure firft difcovered by the late Dr. Monro of Edinburgh. The chief advantage of this ftructure is, that this fluid, when confined, has all the refiftance of a folid body, without its hardnefs, which in this part might be attended with very bad confequences.

The head is connected to the upper vertebra of the neck by two fmooth projections of that vertebra, which are called the condyls, being received into two correfponding cavities in the under part of the cra-

 nium.

nium. By means of this joint we move the head backwards and forwards on the ſpine, or perform the action of nodding. As it is neceſſary, however, for the head to have alſo a rotatory motion, we here find a peculiarity of ſtructure to which there is nothing ſimilar in any other part of the body. In the upper ſurface of the ſecond vertebra of the neck there is a long tooth-like proceſs or projection, which is received into a perforation of the firſt vertebra. This proceſs is rendered ſmooth by a covering of cartilage; it paſſes quite through the vertebra above it, and is connected to this as well as to the cranium by ſtrong ligaments, which give ſtrength to the connection, and guard againſt the effects of a too extenſive motion. The rotatory motions of the head, therefore, are not performed on the firſt vertebra of the neck, but on the ſecond; the firſt vertebra, with the head, moving on the tooth-like proceſs of the ſecond vertebra, as a wheel moves on its nave.

The ſpine, however, though it forms a column, does not form by any means an upright column. The ſpine, viewed ſideways, if the os ſacrum is conſidered as a continuation of it, is bent very much in the form of the letter *ſ*. In the neck it projects ſomewhat forwards, lower down it takes a curved direction backwards, to make room for the heart and lungs. In the loins it advances again forwards under the center of gravity, ſo as to ſupport the abdominal viſcera; and in the pelvis it recedes backwards, ſo as conſiderably to enlarge that cavity.

Each vertebra is divided into a body and ſeven projections, apophyſes or proceſſes. The body is placed before, it is ſmooth, of a roundiſh form, and a remarkably ſpongy texture. The proceſſes are of a much firmer texture, and project backwards. Two

of these processes are called the superior oblique, and ascend obliquely from the upper part of the vertebra; two are called the inferior oblique, and descend obliquely from the lower part; two are called the transverse, and project sideways; and one is called the spinous, from its resemblance to a thorn, which projects directly backwards. Of these processes the spinous and transverse are the most prominent. The oblique processes seem chiefly designed for the articulation of the vertebræ with each other, and are therefore also called articular processes. All the vertebræ are perforated for the reception of the spinal marrow, and also have notches for the transmission of nerves.

The uses of the spine are to support the body in an erect posture, and at the same time, by the number of joints with which it is furnished, to admit of a free motion, without danger of compressing the spinal marrow, which it is designed to protect. It is formed larger below than above, because the lower parts of it have a greater weight to support than the upper; and because, when the body is bent, that weight acts with the longest lever against that part of the spine which is farthest removed from it.

In very young children, each vertebra consists of three pieces of bone united by cartilage. As the spine contains so important a part as the spinal marrow, we observe a solicitous care taken by Providence, that the vertebræ should not be disjointed. Besides being connected by strong ligaments, proportioned to the forces which are to be resisted, the vertebræ of the neck enter into each other, those of the back are propped by the ribs, and those of the loins have so large a surface of contact, as to render their separation almost impracticable.

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The thorax is a bony cavity, narrow above, wide below, and arched behind and at its ſides.

The ſternum or breaſt-bone, which forms the anterior part of the thorax, is of a ſpongy conſiſtence, and of a flat and nearly triangular form; in infancy it conſiſts of many parts, in the adult ſtate of only two, or ſometimes three. The upper part is broad and thick, the lower narrow and thin. The loweſt part of the ſternum, from its reſemblance to a dagger, and its cartilaginous nature, is called cartilago enſiformis. The upper part of this bone is notched for the paſſage of the wind-pipe, and there are two cavities in its ſides for the articulation of the clavicles or collar-bones. There are alſo ſeven ſmall holes on each ſide, for the articulation of ſeven ribs. Its uſes are to ſupport the ribs, to protect the lungs and heart, and to furniſh connection to a muſcular organ, which will be afterwards conſidered, called the diaphragm.

The ribs which conſtitute the greater part of the cavity of the thorax, are ſomewhat of a ſemicircular form; they paſs from the ſpine towards the ſternum; they are not connected, however, to the vertebræ themſelves, but to the cartilagino-ligamentous ſubſtance which connects the vertebræ to each other. At the poſterior part the rib has two proceſſes; one of theſe, by which it is connected between two vertebræ, is called its head; another is articulated with the tranverſe proceſs of the vertebræ immediately below, and is called its tuberoſity. Advancing farther on this external ſurface, we obſerve on moſt of the ribs another ſmaller tubercle, into which ligaments connecting the ribs to each other, and to the tranſverſe proceſſes of the vertebræ, and portions of the longiſſimus dorſi, are inſerted. Beyond this the ribs

make a conſiderable curve, ſometimes called their angle. The ribs then begin to become broad, and continue ſo to their anterior end, whereas near the ſpine they are nearly round. To the fore end of each rib a long broad and ſtrong cartilage is fixed, and reaches thence to the ſternum, or is joined to the cartilage of the next rib. The ribs are twenty-four in number, twelve being placed on each ſide. They are divided into the true and the falſe ribs; the ſeven uppermoſt on each ſide, which are connected to the ſternum, being called *true*, and the remaining five *falſe*.

The upper rib is ſo placed, that its connection with the ſternum is ſomewhat higher than that with the ſpine, and the two connections of the ſecond rib are about horizontal; all the other ribs, however, point obliquely downwards, as they approach the ſternum, and this obliquity increaſes as we advance lower. A neceſſary conſequence of this ſtructure is, that when the ribs are raiſed, they muſt be brought nearer to a right angle with the ſpine, and that the cavity of the cheſt muſt be enlarged. The upper rib is fixed, but the ſecond and every ſucceeding rib is gradually more moveable than that placed immediately above it.

The ſeven upper ribs, called the true ribs, are, as was before remarked, connected to the ſternum; the three upper of the falſe ribs are not connected to the ſternum, but adhere to each other, and to the cartilaginous anterior part of the loweſt of the true ribs. The two loweſt of the falſe ribs are only connected to the ſpine by one articulation, and have their other end no otherwiſe ſupported than by the muſcles and membranes with which they are ſurrounded. By this ſtructure the trunk of the body is rendered more flexible at its lower part, where moſt motion is required.

The uſes of the ribs are to form the lateral parts of the

the thorax; to render the cavity of the thorax larger or ſmaller in breathing; to protect the viſcera of the thorax; to give origins and inſertions to a variety of muſcles; and to ſupport the mammæ or breaſts.

The pelvis, ſo called from its reſemblance to a baſin, conſtitutes the loweſt part of the trunk. Its poſterior part is formed by the os ſacrum, and its lateral and anterior parts by the oſſa innominata.

The os ſacrum may be conſidered as a continuation of the ſpine; and ſome anatomiſts have called both this bone and the os coccygis by the name of the falſe vertebræ. The os ſacrum is a large thick bone, of a triangular form; its broadeſt part is placed uppermoſt, and its narroweſt is turned downwards and inwards. The poſterior ſurface of this bone is convex, the anterior concave. The two lateral margins of it are incruſted with cartilage, by the help of which it is immoveably connected with the oſſa innominata. In the middle of this bone there is a canal for the ſpinal marrow, correſponding with that in the vertebræ of the ſpine; and on the anterior ſurface there are ten perforations, for the paſſage of as many nerves. On the poſterior part there are many protuberances, which, like the proceſſes of the vertebræ, ſerve for the inſertion of muſcles.

The os coccygis is a ſmall bone of a pointed ſhape, adhering to the lower part of the os ſacrum. The os coccygis is in infancy compoſed of ſeveral pieces of bone, which coaleſce, however, in the adult ſtate. It may be conſidered as a continuation of the os ſacrum, and is bent in the ſame direction with that bone.

The oſſa innominata, which form the ſides and fore part of the pelvis, are two large broad bones, which in infancy conſiſt each of them of three diſtinct pieces; but as we advance in life, the intermediate cartilages

gradually oſſify, and the marks of the original ſeparation diſappear, ſo that they become one irregular bone. They ſtill, however, retain the names of ileum, iſchium, and pubis, by which their diviſions were originally diſtinguiſhed, and are deſcribed as three different bones, by the generality of anatomiſts. The oſſa innominata are connected poſteriorly to the os ſacrum, by a firm cartilaginous ſubſtance.

The os ileum or haunch-bone, forms the higheſt and moſt conſiderable part of the os innominatum. The external ſide of the ileum is unequally convex, and is called its dorſum: the internal concave ſurface is by ſome authors named its coſta. The ſemicircular edge at the higheſt part of this bone, which is tipped with cartilage in the recent ſubject, is named the ſpine. This has two conſiderable projections; one anterior, and the other poſterior, which is the larger of the two. Theſe ends of the ſpine being more prominent than the ſurface of the bone below them, are therefore called the anterior and poſterior ſpinous proceſſes. Below the anterior ſpinous proceſs another protuberance projects, which by its ſituation may be diſtinguiſhed from the former, by adding the epithet of *inferior*. Between theſe two anterior proceſſes, the bone is hollowed. Below the poſterior ſpinal proceſs a ſecond protuberance of the edge of this bone is alſo to be obſerved, which is cloſely applied to the os ſacrum. Under this laſt proceſs a conſiderable niche is obſervable in the os ileum; between the ſides of which and the ſtrong ligament which is ſtretched over from the os ſacrum to the ſharp-pointed proceſs of the os iſchium of the recent ſubject, a large hole is formed, through which the muſculus pyriformis, the great ſciatic nerve, and the poſterior crural veſſels, paſs, and are protected from compreſſion. The internal ſurface of the os ileum is

concave

concave in its broadeſt fore part, whence a ſmall ſinuoſity is continued obliquely forwards, at the inſide of the anterior ſpinous proceſs. This ridge is continued from the os ſacrum, and correſponds with a ſimilar prominence, both of that bone and of the iſchium, and forms, with the inner part of the os pubis, what is called the brim of the pelvis. The poſterior and lower parts of the oſſa ileum are thick; but at their middle, where they are expoſed to the actions of ſeveral ſtrong muſcles, and to the preſſure of the abdominal viſcera, they are exceedingly thin and compact.

The oſſa iſchii or hip bones, form the lower and lateral parts of the pelvis: each is commonly divided into its body, tuberoſity and ramus. From the body of the iſchium the ſharp ſpinous proceſs ſtands out backwards, to which the anterior or internal ſacroſciatic ligament is fixed. Between the upper part of the ligament and the bones, it was formerly obſerved that the ſciatic nerve, &c. paſs out of the pelvis. The tuberoſity, or loweſt part of the iſchium, is large and irregular, affords an origin to ſeveral muſcles, and is the part on which the body reſts in the poſture of ſitting. From the tuberoſity the bone becomes thinner and narrower; and paſſing forwards and upwards, concurs with the ramus of the os pubis, to form a large hole, called the foramen magnum iſchii, or thyroideum. This hole, which in the recent ſubject is cloſed with a ſtrong membrane, called the obturator ligament, affords through its whole circumference attachment to muſcles.

The oſſa pubis conſtitute the anterior, or, when the body is erect, the lower part of the pelvis. They are of an irregular form, and as well as the other parts of the oſſa innominata have a ſhare in forming the acetabulum. The two oſſa pubis are joined together by

cartilage at the fore part of the pelvis, which is called the ſymphyſis pubis. In each os pubis we may obſerve the body of the bone, its angle, and ramus. The body or outer part is united to the os ileum; the angle comes forwards to form the ſymphyſis, and the ramus is a thin proceſs which unites with the ramus of the iſchium to form the foramen thyroideum.

The acetabulum, or ſocket of the thigh-bone, which is partly formed by all the three bones which conſtitute the oſſa innominata, is placed at the under part of the pelvis, and is turned obliquely outwards. The acetabulum is not a perfect circle in the ſkeleton, the under part being ſupplied in the recent ſubject by cartilage.

The os pubis conſtitutes about one-fifth of the acetabulum, the os ileum makes ſomething leſs than two-fifths, and the os iſchium as much more than two-fifths.

The pelvis has two openings, one above and one below; that above, when we ſtand in the erect poſture, pointing almoſt directly forwards, that below, almoſt directly backwards.

The chief differences between the male and female ſkeletons are in the proportions of the bones of the pelvis. The cavity of the male pelvis is an irregular circle; that of the female is much larger, and of an oblong ſhape; the longeſt diameter being from ſide to ſide, and the ſhorteſt from the os ſacrum to the oſſa pubis. Hence women are much wider acroſs the hips, in proportion to their height, than men. The os ſacrum is broader, and turned more backwards for enlarging the pelvis. The os coccygis is more moveable, and much leſs bent forwards, to facilitate delivery. In conſequence of the pelvis being wider in women, the articulations of their thigh-bones

bones muſt be farther removed from each other, which gives them a different gait from men in running, as they muſt throw the weight of their bodies further from ſide to ſide in order to bring it over the center of gravity. The bones in general are much finer and leſs robuſt in the female than in the male ſkeleton, and the collar-bones are leſs curved. The oſſification of ſome of the bones is alſo in women leſs complete.

The principal uſes of the pelvis are to form an arch between the trunk of the body and the lower extremities; to contain and protect the urinary bladder, the lower part of the inteſtinal canal, &c.

Chap. VIII.

THE BONES OF THE INFERIOR EXTREMITY.

The Os Femoris.— Bones of the Leg.—The Foot.

THE bones of the lower extremities are divided into the thigh-bone, the bones of the leg, and the bones of the foot.

The os femoris, or thigh-bone, is the longeſt bone in the body, and is the largeſt, thickeſt, and ſtrongeſt of the cylindrical bones. The lower extremities are connected to the trunk by the head of the os femoris being received into the acetabulum. The thigh-bone is not placed in a perpendicular direction, the upper ends of the thigh-bones being much farther apart than the lower; and from the greater width of the pelvis in women, this difference is much more remarkable in them than in men. The body of this bone is ſomewhat of a triangular form; it is convex before and flat behind, and is marked particularly behind by bony ridges, which ſerve for the connection of muſcles. This bone is perforated at one or two places for the reception of blood-veſſels.

The os femoris is not a ſtrait bone, but is arched conſiderably forwards. Its head is turned inwards, and the neck is almoſt horizontal, conſidered with reſpect to its ſituation with the body of the bone. Throughout two-thirds of the length of the thigh-bone, at its poſterior part, we obſerve a ridge called the linea aſpera, which originates from the trochanters,

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and after running ſome way, divides into two ſmaller ridges, which terminate at the condyls *.

The head of the os femoris is nearly round, and is marked in the center with a round pit, into which a ligament, which ſerved to keep it fixed in the ſocket, was inſerted. The neck is narrower above and thicker below, and is terminated by a ridge, to which the capſular ligament of the joint was attached. Below this ridge are two remarkable proceſſes called the trochanters. The larger of the trochanters is directed outwards, and is placed at the other ſide of the thigh-bone; the other is placed behind, but points inwards. The ſurfaces of both the trochanters are very rough, for the inſertion of muſcles From the muſcles inſerted into theſe two proceſſes being the principal inſtruments of the rotatory motions of the thigh, they are called trochanters.

The lower extremity of the thigh-bone is thick, and terminates in two condyls which are very cloſe to each other before, but conſiderably removed behind, where there is formed a ſafe canal, through which a large artery paſſes to arrive at the leg. Behind are alſo two cavities which receive ligaments croſſing each other for ſtrengthening the connection of the os femoris with the larger bone of the leg. The os femoris is united to the trunk by that kind of joint which admits of motion in all directions; but here this motion is in ſome directions much limited by the capſular ligament of the joint. The ſubſtance of this bone, as of all the cylindrical bones, is firm in the middle, and ſpongy towards the extremities.

* By the word *condyl* is meant the large extremity of a bone, reſembling the knob of a clubbed ſtick.

The leg has three bones, the tibia, the fibula, and the patella. The tibia, which is the principal bone of the leg, is a cylindrical bone of a triangular form, larger above than below. The upper end of the tibia is large, bulbous, and ſpongy, and is divided into two cavities by a rough irregular protuberance, which is hollow at its moſt prominent part, as well before as behind. The two broad cavities at the ſide of this protuberance are not equal; for the internal is oblong and deep, for receiving the internal condyl of the os femoris; while the external is more ſuperficial and rounder, for the external condyl. The circumference of theſe cavities is rough and unequal, for the firm connection of the ligaments of the joint. In this manner is formed a hinge or joint, which admits of motion in only two directions. At the back part of this bone the ſame canal is continued between the condyls, for tranſmitting blood-veſſels and nerves, as in the os femoris; and there are two eminences for the inſertion of the other ends of the crucial ligaments. At the interior part of this bone is a cavity for the reception of the patella, which correſponds with one between the condyls of the os femoris. Below the external edge of the upper end of the tibia is a flat ſurface of cartilage, for the connection of the fibula; and at its lower end there is a longitudinal cavity on the outſide, for receiving the lower part of the ſame bone. On the internal part of the bottom of the tibia is a proceſs, which forms the inner malleolus or ankle-bone. Still lower, at the extremity of the tibia, is a tranſverſe articulating cavity, covered with cartilage, and divided by a ridge, which receives a bone of the foot called the aſtragalus. The body of the tibia has three angles, and as many flat ſurfaces. One of the flat ſurfaces

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is turned directly backwards, and one of the angles is placed directly at the fore-part of the bone, and is that ſharp ridge which is felt by the finger, being only covered by the common integuments of the body. Another angle is called the poſterior and internal, and terminates in the inner ankle-bone; and the third is called the poſterior and external angle, and gives connection to the interoſſeous ligament, which paſſes from this bone to the fibula.

The fibula, which is nearly oppoſed to the laſt-mentioned angle of the tibia, is a triangular and very thin bone, nearly as long as the tibia. Its ſuperior extremity is united to the head of the tibia by means of cartilage. Its head does not riſe quite ſo high as that of the tibia, and has therefore no connection with the os femoris; its lower extremity is ſlightly connected to the aſtragalus, and forms the external ankle. Its chief uſes are to afford room for the connection of muſcles, to extend the interoſſeous ligament, and to give greater firmneſs to the connection of the tibia with the foot.

The patela, rotula, or knee-pan, is a ſmall flat bone of a ſomewhat triangular form, which is placed at the fore part of the leg, where the tibia is connected with the os femoris. The anterior convex ſurface of the patella is pierced by a great number of holes, into which enter fibres of the ſtrong ligament which is ſpread over it. Behind, its ſurface is ſmooth, covered with cartilage, and divided by a middle convex ridge into two cavities, both of which are exactly adapted to the pulley of the os femoris. The ſubſtance of the patella is cellular, but the cells are ſo ſmall that it is a very ſtrong bone. Its uſes are to protect the joint, and to anſwer the purpoſe of a pulley to the muſcles which extend the leg.

The foot is compoſed of the bones of the tarſus. metatarſus, and toes. It is convex above, concave below, and has a conſiderable projection behind.

The tarſus, which is connected with the bones of the leg, conſiſts of ſeven pieces of bone, the aſtragalus, the os calcis, the os naviculare, the os cuboideum, and the three oſſa cuneiformia. The aſtragulus occupies the poſterior and upper part of the foot, and is the bone on which the bones of the leg immediately depend for ſupport. The os calcis forms the projection of the heel; it is of a very irregular form, and is divided into the body, which points backwards, and an anterior proceſs by which it is connected with the aſtragalus and the os cuboideum. The os naviculare is placed before the aſtragalus, and towards the inſide of the foot; it derives its name from its ſuppoſed reſemblance to a boat. The os cuboideum is placed before the os calcis, and towards the outſide of the foot. The three oſſa cuneiformia are placed before the os naviculare, near to each other, and are ſo called from their appearing like wedges driven in among the other bones of the foot. The ſubſtance of the oſſa tarſi is ſpongy, and they are ſo connected together by cartilage as not to admit of much motion upon each other.

The metatarſus conſiſts of five cylindrical pieces of bone, interpoſed between the tarſus and the bones of the toes. Their upper ſurface is convex, their lower ſurface concave; their poſterior extremity is concave where they are connected with the tarſus, and their anterior extremity is furniſhed with condyls, by which they are faſtened to the bones of the toes.

The bones of the toes are connected to thoſe of the metatarſus. The great toe has only two joints, the reſt three, and in this reſpect they reſemble the fingers and the

the thumb. There are ſometimes found ſmall bones, which are called oſſa ſeſamoidea; theſe chiefly occur between the firſt and ſecond joints of the great toe and thumb, and as they anſwer the ſame purpoſes, viz. that of removing the tendon further from the axis of motion, may be conſidered as ſmall patellæ. They are almoſt excluſively found in perſons advanced in life and inured to hard labour, and therefore are by ſome ſuppoſed to owe their origin to friction.

Chap. IX.

THE BONES OF THE SUPERIOR EXTREMITY; WITH A BRIEF COMPARISON OF THE HUMAN SKELETON WITH THAT OF BRUTES.

Bones of the Humerus.—Os Bracchii.—Antibracchium.—Bones of the Hand.—Refemblance between the fuperior and inferior Extremities.—Comparifon between the Human Skeleton and that of Quadrupeds.

THE fuperior extremity is divided into the humerus or fhoulder; the brachium or arm; the antibrachium or fore-arm; and the manus or hand.

The humerus is compofed of two bones, the fcapula or fhoulder-blade, and the clavicula or collar-bone. The point where thefe two bones unite is the top of the fhoulder. The fcapula is a flat thin bone of a triangular fhape. It is fituated at the upper part of the back, and extends from the firft to about the feventh rib. One of the furfaces of the fcapula, which is concave, is applied to the trunk of the body; the other, which is convex, and more uneven, is turned outwards; fo that the form of the bone may be plainly difcerned in the living perfon. The external furface is divided by a projecting ridge of bone, called the fpine of the fcapula, into two parts, the upper of which is much narrower and fmaller than the lower. The fcapula has three angles, and three fides or margins. With refpect to the margins, that which is placed next the fpine is by far the longeft, and is therefore fometimes called the bafe of the fcapula; that which forms the upper part of the bone is nearly horizontal, and is parallel to the fecond rib, and is the fhorteft and thinneft;

the remaining margin, which defcends obliquely from the point of the fhoulder to the inferior angle, is by far the thickeft and ftrongeft.

The proceffes of this bone are the coracoid, fo called from its refemblance to a crow's beak, which rifes from the anterior part of the fuperior margin of the fcapula; and the acromion, which is a broad and flat procefs of the fpine, placed at the top of the fhoulder, and is the whole thick bulbous fore part of the bone. Near the fore part of the fuperior margin is a femilunar niche, from one end of which to the other a ligament is ftretched; and fometimes the bone is continued to form one or two holes for the paffage of the fcapular blood-veffels and nerves. From the niche to the termination of the foffa (in which a mufcle called the teres major is attached) the fcapula is narrower than any where elfe, and this part has therefore been called its neck.

The cavities of the fcapula are the glenoid cavity, wider below than above, and covered with cartilage for the reception of the bone of the arm; and feveral fmaller cavities for the connexion of mufcles, and other ufes.

The texture of the fcapula is firm, but the bone is fo thin as at moft places to be tranfparent. It is connected by a ball and focket to the bone of the arm; by the intervention of cartilage to the clavicle; and with the head, the os hyoides, the fternum, the ribs, and the back-bone, by means of mufcles. Its ufes are for the articulation of the arm-bone, for the infertion of a great number of mufcles, to add force and extenfivenefs to the motions of the arm, and to be a defence to the pofterior part of the trunk.

The clavicula, clavicle, or collar-bone, is a cylindrical bone, placed almoft horizontally between the

ſide of the ſternum and the acromion of the ſcapula. Its figure is ſomewhat like that of the letter *ſ*; and it received its name from a ſuppoſed reſemblance to the key uſed among the ancients. The clavicle, as well as other long cylindrical bones, is larger at its ends than at its middle. The end next the ſternum is triangular: the angle behind is conſiderably protruded, to form a ſharp ridge, to which the tranſverſe ligament, extended from one clavicle to the other, is fixed. It is for the moſt part convex without, and concave within. One end of the clavicle is connected by a ball and ſocket with the ſternum, and the other by cartilage to the acromion of the ſcapula. Its uſes are to ſupport the ſhoulder and other parts of the ſuperior extremity, to protect ſome large veſſels in their paſſage to the arm, and to connect the ſcapula to the thorax.

The os brachii, or as it is ſometimes called the os humeri, is a cylindrical bone, the round head of which is received into the glenoid cavity of the ſcapula. It is larger and rounder at its upper part, and ſmaller and flatter below. It has three projecting lines, and as many flat ſurfaces, by which form it admits of a more advantageous and extenſive connexion of muſcles, than if it had been a ſimple cylinder, which is not the caſe with any bone of the body, though all the long bones approach to that form. This bone has many circumſtances of ſtructure in common with the os femoris. Like that bone it is articulated by a round head, which is ſurrounded by a capſular ligament, and, like it, has proceſſes for the connexion of muſcles; but theſe proceſſes are much leſs remarkable in the os humeri than in the os femoris. At the lower extremity of this bone we obſerve ſeveral proceſſes and cavities. The moſt remarkable proceſſes are the two condyls; of theſe the external is the ſmalleſt, and is of an irregular ob-

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long ſhape. The internal is more protuberant, and ſerves, as well as the former, to give origin to many muſcles. Between theſe two condyls are two lateral protuberances, which, together with a middle cavity, form a kind of pully, on which the motions of the fore-arm are chiefly performed.

The antibrachium, or fore-arm, conſiſts of two bones, the ulna and the radius. The ulna, which is the longer of the two bones, and is that by which the fore-arm is chiefly connected with the arm, is large above and ſmall below, and is of an irregular cylindrical form. At the ſuperior extremity of the ulna there are two proceſſes, a larger one called the olecranon, placed poſteriorly, and a ſmaller, called the coronoid, at the anterior part. At the upper end of the ulna, between theſe proceſſes, is a cavity divided by a projecting line, and covered with ſmooth cartilage, for the reception of the correſponding projections of the os humeri. There is another cavity at the ſide of the coronoid proceſs, covered with cartilage, on which the ſuperior end of the radius rolls in ſome of the motions of the hand. At the lower extremity of the ulna, which is much ſmaller than the upper, is a head with a ſlight excavation, and a ſmall proceſs called the ſtyloid, which forms a projection at the lower end of the fore-arm, on the ſame ſide with the little finger, not unlike the ankles. The ulna is firmly connected above, by a hinge joint, to the os humeri, laterally to the radius, and ſlightly below to the carpus, and its articulations are every where firmly ſecured with ligaments.

The radius is a bone of nearly the ſame form, ſize, and appearance, with the ulna. As the larger end of the ulna is firmly connected with the os humeri, ſo that of the radius is connected to the carpus. On the contrary, the connexions of the ulna with the carpus, and

of the radius with the os humeri, are very inconsiderable; the smaller end of the one bone being opposed to the larger of the other, and depending on it for support and firmness. The ends of these two bones are closely joined together; their middle parts recede from each other, with the interposition of an interosseous ligament, similar to that between the tibia and fibula. At the upper end of the radius is a small cavity, which receives the outer protuberance of the os humeri, and the projecting ridge surrounding this cavity rolls in a small sinus at the upper end of the ulna, in which situation it is held by a ring of cartilage. At the bottom of the radius there is also a similar sinus, which receives the lower end of the ulna. The radius is therefore joined to the ulna by a double articulation; for, above, a tubercle of the radius plays in a socket of the ulna, whilst below, the radius affords the socket, and the ulna the tubercle. The motion, however, performed in these two is very different; for, at the upper end, the radius does no more than turn round its axis, while, at the lower end, it moves in a sort of cycloid upon the round part of the ulna; and as the hand is here articulated and firmly connected to the radius, they must move together. The ulna, being connected by a hinge-joint to the os brachii, has scarcely any other motion than that of flexion and extension, in which it carries with it the radius. The motions of the hand, in which the palm is turned either upwards or downwards, are performed by those of the radius on the ulna, carrying with it the hand. From these circumstances it appears, that the ulna more particularly belongs to the os humeri, and the radius to the carpus. The ulna sometimes carries with it the radius, but the radius never moves the ulna, which, like the tibia is connected by a hinge-joint, and has motion only

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in two directions. The radius is ſo intimately connected with the hand, and is ſo much employed ln its principal motions, that it has been called *manubrium manus*, or the handle of the hand. Without this peculiar mechaniſm, the motions of the fore-arm would be as confined as thoſe of the leg; but providence, which has preferred the more firm and ſecure ſtructure in a part which was deſtined to ſupport the body, has adapted the fore-arm, by this beautiful and admirable contrivance, for the performance of a number of motions, with which a hinge-joint would be quite incompatible.

The bones of the hand are divided into thoſe of the carpus, metacarpus, and fingers. The carpus or wriſt is formed of eight bones, which are ſmall, of irregular ſhapes, and diſtinguiſhed into two ſeries. The form of the carpus is ſquare; that ſurface, which is contiguous to the palm of the hand, is concave, the oppoſite is convex. Each of the two ſeries of bones, which compoſe the carpus, conſiſts of four pieces. The firſt ſeries, or that which is placed next the bones of the fore-arm, conſiſts of the os naviculare, the os ſemilunare, the os cuneiforme, and the os piſiforme. The bones, which form the other ſeries, are the os multangulum majus, the os multangulum minus, the os capitatum, and the os cuneiforme. Theſe bones are covered with cartilage, and are variouſly articulated with the bones with which they are in contact. The principal uſe of ſo great a number of bones in the wriſt is to render the hand more flexible. The back part of the hand is convex, for greater firmneſs and ſtrength; the palm concave, for containing more ſurely and conveniently ſuch bodies as we take hold of. The upper part of the hand has an obſcure motion in compariſon with the remainder, and ſerves as a baſe to the fingers.

With reſpect to the metacarpal bones, and thoſe of the fingers, they are ſo nearly ſimilar to thoſe of the metatarſus and toes, that nothing need be added concerning them.

The reader muſt undoubtedly have been ſtruck with the great reſemblance of ſtructure between the inferior and ſuperior extremities. The os humeri has many points of reſemblance to the os femoris, the tibia and fibula to the radius and ulna, and the bones of the carpus, metacarpus, and fingers to thoſe of the tarſus, metatarſus, and toes.

Before the anatomy of the bones, however, is concluded, it will be proper to make a few general remarks on the ſkeleton of quadrupeds.

In quadrupeds we obſerve the ſame general outlines of ſtructure in the oſſeous ſyſtem as in man. Their ſkeletons divide themſelves into head, trunk, and extremities; and each of theſe diviſions bears a ſtriking reſemblance to the ſame diviſion in the ſkeleton of the human body. The cavity of the cranium is much ſmaller in quadrupeds than in man, in proportion to the other parts, but the bones of the face are much longer; and with reſpect to this circumſtance, as well as many others, the monkey holds a middle place between mankind and quadrupeds.

The ſpine, as in man, is connected to the cranium; but in quadrupeds, this bony column, inſtead of being placed vertically, is placed horizontally; in both, however, the ſtructure is the ſame, and the part is ſubſervient to the ſame purpoſes. The other parts of the trunk are alſo very ſimilar to the ſame parts in man; and the form and relative ſituation of the ſternum and ribs are nearly the ſame, but the latter are more numerous in quadrupeds. The ſame reſemblance is manifeſted in the bones of the pelvis, except

cept that the os coccygis is continued beyond the other parts of the body, and forms the tail. The upper part of both extremities, as in man, is formed of one piece of bone, the lower part of two, and in many quadrupeds there are bones which correfpond with the carpus and tarfus, the fingers and the toes. The clavicula or collar-bone is in general, however, wanting in quadrupeds, and is only found in monkeys, fquirrels, and fome other animals, which are fkilful in climbing, and which employ their fore legs for other purpofes than that of travelling. In fhort, the fkeleton of the quadruped is fo fimilar to that of man, that when the fkeleton of the former is placed erect on the hind-legs, it may eafily, by perfons unacquainted with anatomy, be miftaken for that of the latter.

The figure in Plate II. reprefents a front view of the human fkeleton, with fome of the ligaments and cartilages, which connect the bones to each other.

HEAD *and* NECK.

a, Os frontis.

b, Os parietale.

Between *a* and *b*, part of the coronal future.

c, The pars fquamofa of the temporal bone.

Between *b* and *c*, the fquamous future.

Below the pars fquamofa, the zygoma; and, lower down, above *f*, the maftoid procefs.

Between the pars fquamofa and the cavity, which contains the eye-ball, called the *orbit*, the temporal procefs of the fphenoid bone is feen.

d, Os malæ.

Above *d*, a portion of the tranfverfe future.

e, Os maxillare fuperius, with the eight teeth of the right fide,

The nasal process of the superior maxillary bone has the os nasi joined, by the lateral nasal suture, to its inside; and at the outside, within the orbit, the os unguis.

The ossa nasi joined to each other before, by the anterior nasal suture.

f, Os maxillare inferius with sixteen teeth; the four anterior named *incisores*, the two corner ones *canini*, and the five posterior on each side *molares*.

Opposite to *f*, the angle of the lower jaw; above *f*, the condyloid process, by which the jaw is connected to the temporal bone, at the root of the zygoma; and behind the os malæ, the coronoid process.

g, The seven cervical vertebræ, with their intermediate cartilages.

Opposite to *g*, their tranverse processes.

Trunk.

a, Sternum.

a, its middle piece, to which one half of the cartilage that connects the second rib, the whole of the cartilages of the third, fourth, fifth, sixth, and one half of the seventh, are fixed.

Above *a*, the first or upper triangular piece, to which the clavicle and one half of the cartilage that connects the second rib are fixed.

Below *a*, the extremity, or third piece of the sternum, named the *cartilago ensiformis*, to which one half of the cartilage that connects the seventh rib is fixed.

b, The seventh, or last true rib.

c, The twelfth, or last of the five false ribs.

d, The five lumber vertebræ, with their intermediate cartilages.

Opposite

Oppoſite to *d*, their tranſverſe proceſſes.

e, The os ſacrum, with its five diviſions.

f, Os innominatum, divided into

g, Os ilium,

h, Os pubis,

i, Os iſchium,

Oppoſite to *i*, the foramen thyroideum.

Superior Extremity.

a, The clavicle, fixed before to the firſt piece of the ſternum, and outwards to the acromion of the ſcapula.

b, The ſcapula.

Above *b*, the cervix of the ſcapula.

Oppoſite to it, the inferior coſta; and below the outward extremity of the clavicle, the ſuperior coſta, and coracoid proceſs, are ſeen.

c, the os humeri.

The upper end of it, which is connected to the cavity of the ſcapula, named the *glenoid*, below the acromion, is named its *head* or *ball*; on each ſide of which is ſeen the tubercles, named the *external* and *internal*; and between theſe, a groove for lodging the long head of the biceps flexor cubiti.

d, The internal condyl.

e, The external condyl.

Between *d* and *e*, the trochlea, upon which the ulna moves.

f, The radius.

The upper end, which moves on the external condyle of the os humeri, is named its *head*; below that, the tubercle for the inſertion of the biceps flexor cubiti, and between theſe the cervix.

The inferior end of it is connected to the carpus.

g, The ulna.

The upper end of it forms the coronoid procefs, for the infertion of the brachialis mufcle.

The inferior end has a procefs named the *ftyloid*, which is connected to the carpus by a ligament.

h, The carpus, formed of eight bones.

i, Metacarpal bone of the thumb.

k, The metacarpal bones of the four fingers.

l, The two joints of the thumb.

m, The three joints or phalanges of the fore-finger; and the fame are feen in each of the other three.

INFERIOR EXTREMITY.

a, The os femoris.

The upper end of it is named its *head* or ball, which is lodged in a deep focket of the os innominatum, named the *acetabulum*.

Between the head and trochanter major, the cervix.

b, Trochanter major.

c, Trochanter minor.

d, Internal condyl.

e, External condyl.

f, Patella.

The place where it moves upon the os femoris, is named the *trochlea*.

g, Tibia.

Between the tibia and the condyls of the os femoris, the femilunar cartilages are feen; and below the joint, the tubercle of the tibia.

h, Fibula.

i, Malleolus internus.

k, Malleolus externus.

l, Os

l, Os calcis.

Between *l* and *m*, the other ſix bones of the tarſus.

m, Metatarſal bones of the four toes.

n, The three joints, or phalanges, of the four toes.

o, Metatarſal bone of the great toe.

p, The two joints of the great toe.

The figure in plate III. repreſents a back view of the human ſkeleton, with ſome of the ligaments and cartilages which connect the bones.

Head *and* Neck.

a, Os parietale, joined to its fellow by the ſagittal ſuture.

b, The os occipitis, joined to the parietal bones by the lambdoid ſuture, which is between *a* and *b*.

c, Os malæ.

d, Maxilla inferior, with a view of the teeth of both jaws from behind.

e, The ſeven cervical vertebræ.

Trunk.

a, The ſeventh or laſt true rib.

b, The twelfth or laſt rib.

c, The five lumber vertebræ.

d, Os ſacrum.

e, Os coccygis.

f, Os innominatum, divided into

g, Os ilium.

h, Os pubis.

i, Os iſchium.

Superior Extremity.

a, The clavicle, joined outwards to the acromion of the ſcapula.

b, The

b, The ſcapula.
c, Os humeri.
d, Internal condyl.
e, External condyl.
f, Radius.
g, Ulna, its upper end, named *olecranon*; and near the wriſt, its ſtyloid proceſs.
h, The eight bones of the carpus.
i, The metatarſal bone of the thumb.
k, The metatarſal bones of the four fingers.
l, The two joints of the thumb.
m, The three joints or phalanges of the four fingers.

INFERIOR EXTREMITY.

a, Os femoris.
b, Trochanter major, and at the inſide of it the cervix.
c, Trochanter minor.
d, Internal condyl.
e, External condyl.
f, Tibia.
g, Fibula.
h, Malleolus internus.
i, Malleolus externus.
k, The ſeven bones of the tarſus.
l, The metatarſus.
m, The joints or phalanges of the toes.

Chap. X.

STRUCTURE OF THE MUSCLES.

General Deſcription of Muſcles.—Obſervations of the Abbè Fontana.—Of Lewenhoeck.—Muſcles compoſed of ſmall Fibres.—Structure of different Muſcles.—Antagoniſts.—Muſcles of the Fœtus.

THE bones, conſidered with relation to the motions of the body, are merely levers; let us now conſider the ſtructure of the muſcles, which are the immediate ſources of all the motions of the animal machine.

The animal ſubſtance, which the anatomiſt calls muſcle, is that which in common language paſſes under the name of the lean or fleſh of meat. The colour of the muſcles, when they are firſt removed from the body, is red; this colour, however, is not eſſential to them, but is merely owing to the preſence of blood, for when muſcle is cleanſed from blood, it appears white. In every recent muſcle we may at firſt view diſtinguiſh two kinds of fibres; the one kind appears red, and is the true muſcular ſubſtance; the other is tendinous, has a white ſilvery appearance, and has no power of contraction like the former. The tendinous ſubſtance is ſometimes collected into a cord, but is very frequently expanded, ſo as by covering the ſurface of a muſcle, or by pervading its ſubſtance, to afford a very extenſive connexion to muſcular fibres.

The Abbè Fontana has taken great pains to examine the ſtructure of muſcles. He divided muſcular ſubſtance with the point of a ſmall needle till he came to minute threads, which, whatever pains he took, would admit of no further diviſion. Theſe, he examined with a lens,

the diameter of which was one-ninth of an inch; when they appeared to be solid homogeneous cylinders, interrupted at regular distances by very minute lines or wrinkles. These wrinkles, when they were examined in different points of view, might have passed for globules; but upon this circumstance, as the observation went no further, the Abbè does not insist. This undulated appearance has also been observed in nervous and tendinous fibres, examined by microscopes of high magnifying powers. Dr. Monro, in his observations on the nervous system, gives it as his opinion, that they are to be considered as folds or joints, serving to accommodate the parts to the different states of flexion and extension. In proof of this he finds, that those parts which have this appearance in their relaxed state, lose it when stretched.

Lewenhoeck long ago fancied that he had discovered the ultimate muscular fibre, which he considered as being one hundred times as small as a hair. He afterwards, however, candidly acknowledged, that what he supposed to be a simple fibre, was, in fact, a bundle of them. Notwithstanding, therefore, the microscopical observations of the Abbè Fontana, and other philosophers, we must still acknowledge ourselves ignorant of the structure of the ultimate component parts of muscular substance; and all we are allowed to say is, that their structure is fibrous. These minute fibres, observed by the Abbè Fontana, were tied by cellular substance in small fasciculi or bundles, these bundles are again formed into larger by the same means, and of these fasciculi are composed those contractile masses of flesh called muscles.

Muscles are generally connected at their two extremities to bones, by means of tendons; the largest part

of

of a mufcle is called its belly, and is chiefly compofed of contractile mufcular fibres. That connexion of a mufcle which is leaft moveable is called its origin, that which is moft moveable its infertion: but thefe terms are in many cafes merely relative, for a part of the body which is more fixed in one pofture becomes lefs fo in another. The fibres which compofe a mufcle run either longitudinally, tranfverfely, obliquely, or circularly. If all the fibres which compofe a mufcle run in the fame direction, it is called rectilinear; radiated, if the fibres are difpofed like radii; penniform, if, refembling the plume of a feather, the fibres are fituated obliquely with refpect to the center from which they proceed; compound, if the fibres run in different directions. The majority of the large mufcles of the body are compound.

Moft mufcles have others oppofed to them, which act in a contrary direction, and are called antagonifts. Thus, one mufcle, or one fet of mufcles, bends a limb, another extends it; one elevates a part, another depreffes it; one draws it to the right, another to the left. By thefe oppofite powers the part is kept in a middle direction, ready to be drawn either one way or another, as particular mufcles are thrown into ftronger action. The flexor mufcles exceed the extenfors in ftrength, and for this reafon the eafieft poftures are thofe in which the body or limbs are moderately bent.

When we fpeak of the mufcles of a part, we do not mean thofe which are fituated on it, but thofe which ferve to move it. Thus, what are called the mufcles of the leg, and which are fubfervient to its motions, are placed round the thigh bone; thofe which move the foot, round the bones of the leg, &c.

In

In the fœtus the muscles are evidently inserted into the periosteum only, but in the adult state, when the periosteum adheres much more closely to the bone, the tendons, being confused with the periosteum, pass with that even into the foveoli of the bone.

CHAP. XI.

MUSCLES OF THE HEAD.

Muſcles of the Forehead.—Of the Eye-lids.—Of the Eye.—Of the Noſe.—Muſcles of the Mouth.—Why the Face is the Index to the Mind.—Temporal Muſcles.—Muſcles of the Neck.—Of the Jaw.—The Tongue.—Muſcles of the Palate, &c.

THE ſkin which covers the head is moved by a ſingle broad muſcle, and one ſmall pair. The former of theſe is ſituated immediately below the common integuments, at the back and fore part of the head, with the intervention of a broad tendon, and is called occipito frontalis. Its effect is to draw the ſkin of the head backwards, to raiſe the eye-brows, and wrinkle the ſkin of the forehead.

The corrugator ſupercilii ariſes from the internal angular proceſs of the os frontis, near its joining with the bones of the face; it is inſerted into the inferior and inner part of the occipito frontalis, draws the eye-brows towards each other, pulls downwards the ſkin of the forehead, and cauſes it to wrinkle, particularly between the eye-brows.

The muſcles of the ear will be ſpoken of when it becomes neceſſary to treat of the organs of hearing.

The muſcles of the eye-lids are, the orbicularis palpebrarum, which ſurrounds the eye, and has the effect of ſhutting the eye-lids. The upper eye-lid has alſo a muſcle proper to itſelf, called the levator palpebræ ſuperioris, the effect of which is to raiſe the upper eyelid, and conſequently to counteract the former.

The ball of the eye has ſix muſcles, four ſtrait and two oblique. The ſtrait muſcles all riſe from the bot-

tom of the orbit around the foramen, through which the optic nerve paſſes, and are extended to the fore part of the globe of the eye. Theſe muſcles are named from their uſe. The levator oculi raiſes the ball of the eye, the depreſſor pulls it down, the adductor turns the eye towards the noſe, and the abductor moves the globe outwards. The two oblique muſcles are, the obliquus ſuperior or trochlearis, which, riſing from the bottom of the orbit, runs along the pars plana of the ethmoid bone to the upper part of the orbit, where its tendon paſſes through a cartilaginous ring connected to the os frontis, by which mechaniſm the direction of its force is altered, and its tendon afterwards proceeding a little downwards, and directed outwards at the ſame time, is inſerted half way between the inſertion of the attollens oculi and optic nerve. The effect of this curious muſcle is to roll the eye, to turn the pupil downwards and outwards, and to draw the whole ball nearer to the noſe. The obliquus inferior ariſes from the orbitar proceſs of the ſuperior maxillary bone, and running obliquely outwards is inſerted in the ſpace between the abductor and optic nerve. Its uſe is to draw the globe of the eye forwards, inwards, and downwards, and, contrary to the ſuperior oblique, to turn the pupil upwards towards the inner extremity of the eye-brow. By acting ſucceſſively with all the muſcles of the eyes we are able to roll them.

The noſe is affected by ſeveral muſcles of the face, but only one pair is commonly conſidered as properly belonging to it. This, which is called the compreſſor naris, ariſes externally from the root of the alæ naſi, and running obliquely upwards along the cartilage of the noſe, joins its fellow, and is inſerted into the neighbouring bone. The effect of this muſcle is to compreſs the alæ towards the ſeptum naris, particularly when we

want

want to smell acutely; it also wrinkles the skin of the nose.

The mouth has nine pair of muscles inserted into the lips, where their terminations form a single muscle, which surrounds the mouth. One of these rises from the upper jaw-bone, and is inserted into the angle of the mouth. Its effect is to raise the corners of the mouth, and it is therefore called the levator anguli oris. 2. The levator labii superioris alæque nasi. This rises by two distinct origins; one of these proceeds from the superior maxillary bone immediately below the orbit, the other from the same bone at the inner angle of the eye. It is inserted partly into the upper lip and partly into the outer part of the alæ nasi, raises the upper lip towards the eyes and a little outwards, and also dilates the nostrils, by drawing the alæ nasi upwards and outwards. 3. The depressor labii superioris alaquæ nasi, arises from the upper jaw-bone, where the dentes incisivi and canini are fixed, and is inserted into the upper lip and root of the alæ nasi. When it acts, it draws the upper lip and alæ nasi downwards and backwards.

The three muscles of the mouth, already mentioned, are situated above, the three other pairs are placed below.

4. The depressor anguli oris arises from the lower edge of the maxilla inferior, and is also connected to the neighbouring soft parts. It is inserted into the corners of the mouth, and pulls them downwards. 5. The depressor labii inferioris arises from the inferior part of the lower jaw-bone, near the chin, is inserted into the edge of the lower lip, and pulls it downwards and a little outwards. 6. The levator labii inferioris arises from the lower jaw, where the dentes incisivi and canini are fixed, and, being inserted into the under lip and skin of the chin, draws them upwards.

Three pair of muſcles are alſo ſeated outwards with reſpect to the mouth.

7. The buccinator (or trumpeter) ariſes from both jaws, adheres cloſely to the membrane of the mouth, and is inſerted at its angles. Its effect is to draw the angles of the mouth backwards and outwards, and to contract its cavity, as in blowing a wind inſtrument, and in puſhing our meat between the teeth. 8. The zygomaticus major ariſes from the os malæ, near the zygomatic ſuture, and is inſerted into the angle of the mouth. When it contracts, it draws the angles of the mouth upwards and outwards, and makes the cheeks prominent as in laughing. 9. The zygomaticus minor deſcends obliquely from the prominent part of the os malæ, and is inſerted into the upper lip near the corner of the mouth. Its uſe is to draw the corner of the mouth obliquely upwards and outwards towards the external corner of the eye.

The ſingle muſcle, which was mentioned as being formed by the terminations of all the others decuſſating each other, is called the orbicularis oris, and entirely ſurrounds the mouth. Its uſe is to ſhut the mouth, by contracting and drawing both lips together, and to counteract all the muſcles which contribute to its formation.

The muſcles of the face are the organs, which, being affected by the paſſions, render the human countenance an index of what is paſſing in the mind; and, as all muſcles acquire a greater degree of ſtrength as well as proneneſs to action in proportion to the degree in which they are employed, ſo the countenance becomes impreſſed with a general character, which is the foundation of phyſiognomy. For this reaſon the countenances of old people are more expreſſive, and their likeneſſes more eaſily taken, than thoſe of the young,

though this is partly to be attributed to the wasting of the fat, which in youth fills the interstices between the muscles, and prevents strong lines. To the above principle is to be attributed the greater expression observable in the countenance of a person of a cultivated mind, than in that of a person whose stock of ideas is limited. From all these circumstances it appears, that the cultivation of the mind is the most likely method of increasing the expression and beauty of the countenance.

The muscles of the lower jaw are four pairs, and are those employed in the mastication of the food.

The temporalis muscle has a very extensive origin, from the lower and lateral part of the parietal bone, all the pars squamosa of the temporal bone, from the external angular process of the os frontis, and from the temporal process of the sphenoid bone. From these different origins the fibres descend like radii towards the jugum, under which they pass, and are inserted into the coronoid process of the lower jaw. Its use is to press the lower jaw against the upper, and at the same time to draw it a little backwards. This muscle is covered with a broad tendon, called its aponeurosis, which defends it, and gives origin to a great number of muscular fibres.

The masseter arises from the superior maxillary bone, where it joins the os malæ, and from the inferior and anterior part of the jugum, and is inserted into the angle of the lower jaw, which, when it acts, it presses against the upper.

The pterygoideus internus proceeds from the inner and upper part of the internal plate of the pterygoid process of the sphenoid bone, and from the pterygoid process of the os palati. It is inserted into the angle of the lower jaw internally, and, when it acts, draws it upwards and obliquely towards the opposite side.

The pterygoideus externus takes its origin from the outer ſide of the pterygoid proceſs of the ſphenoid bone, from part of the tuberoſity of the os maxillare adjoining to it, and from the root of the temporal proceſs of the ſphenoid bone. It is inſerted into the neck of the condyloid proceſs of the lower jaw, and pulls it forwards and to the oppoſite ſide, or when both the external pterygoid muſcles act, the fore teeth of the under jaw are puſhed forwards beyond thoſe of the upper jaw.

On the ſide of the neck, towards its fore part, are two muſcles. The external of theſe is a muſcle of the ſkin, and is called platiſma myoides. It ariſes by a number of ſlender fibres from the cellular ſubſtance, which covers the upper parts of the deltoid and pectoral muſcles; in their aſcent they all unite to form a thin muſcle, adhering to the ſkin, and which is inſerted into the lower jaw. It draws the ſkin of the cheek downwards.

The ſterno-cleido-maſtoideus has two origins, one from the ſternum, the other from the clavicle, which, uniting, form one muſcle, which runs oliquely upwards and outwards, and is inſerted into the maſtoid proceſs of the temporal bone. When it contracts, it turns the head to one ſide, and bends it forwards; or when its fellow acts with it, they draw the head directly forwards.

Six pair of muſcles are ſituated between the os hyoides and the lower jaw.

The muſcle, which forms the external layer, is called the digaſtricus. It riſes near the maſtoid proceſs, runs downwards and forwards to the os hyoides, and thence proceeds to the bone of the chin, into which it is inſerted. When it acts, it pulls the lower jaw downwards and backwards, and therefore opens the mouth.

When the lower jaw, however, is fixed by the ſtronger muſcles, which have been already deſcribed, the effect of the digaſtricus is different, for the os hyoides, then becoming the more moveable part, is drawn upwards, and with it the larynx and pharynx, as in the act of ſwallowing.

The mylo-hyoideus paſſes from the inſide of the lower jaw to the os hyoides, and has nearly the ſame effect as the digaſtricus.

The genio-hyoideus alſo paſſes from the os hyoides to the chin, and either raiſes the former or pulls down the latter, according as the lower jaw or the os hyoides is rendered more fixed by other muſcles.

The genio-hyo-gloſſus ariſes from the lower jaw, and is inſerted partly into the os hyoides, and partly into the tongue. This muſcle, according to the direction of its fibres, acts very differently on different occaſions; from the ſeparate action of its fibres it either draws the tongue backwards, extends it out of the mouth, or renders its upper part concave.

Two muſcles paſs from the os hyoides to the trunk. The ſterno-hyoideus proceeds from the ſternum, and pulls the os hyoides downwards. The omo hyoideus ariſes from the ſuperior coſta of the ſcapula, and draws the os hyoides obliquely downwards. It is to be noticed, that when there are two muſcles of equal ſtrength and equal obliquity attached to a moveable part, and they both act together, they draw it in a ſtrait line, the obliquity of the one counterbalancing that of the other.

The ſubſtance of the tongue is muſcular, and is diſtinguiſhed by anatomiſts into ſix pair of muſcles, which it cannot be neceſſary to enumerate. They alſo deſcribe ſix pair of muſcles belonging to the pharynx: theſe I ſhall paſs over in ſilence, and merely

consider it as a muscular bag, forming the upper part of the alimentary canal. There are also several muscles belonging to the palate and uvula, of which the limits of this work do not permit the specification. I shall at present also pass over the muscles of the larynx, as a better opportunity will occur of comprehending them under the description of the parts to which they belong. The same observation is applicable to the muscles of the ear.

Chap. XII.

MUSCLES OF THE TRUNK.

Muscles of the Neck and Back.—Of the Breast.—Of the Ribs.—The Diaphragm.—Muscles of the Abdomen.—Of the Pelvis, &c.

ON the anterior part of the neck, close to the vertebræ, are seated the following muscles:

The longus colli arises from the bodies of three of the vertebræ of the back, and from the transverse processes of most of the vertebræ of the neck. It is inserted into the fore part of all the vertebræ of the neck, and has the effect of drawing it forwards or to one side, according as the muscle on both sides, or that on one only, is called into action.

The rectus capitis internus major proceeds from the extremity of the transverse processes of the third, fourth, fifth, and sixth vertebræ of the neck, is inserted into the cuneiform process of the os occipitis, and bends the head forwards.

The rectus capitis internus minor arises from the fore part of the body of the first vertebra of the neck, is inserted into the condyloid process of the os occipitis, and also bends the head forwards.

The rectus capitis lateralis arises from the anterior part of the point of the transverse process of the first vertebra of the neck, and is inserted into the os occipitis, and bends the head a little to one side.

The large and strong muscles, seated at the posterior part of the trunk, may be divided into four layers and a single pair. The external layer consists of two very broad muscles.

The trapezius arises by a strong round tendon, from the middle of the os occipitis, and from a rough curved line, which extends thence towards the mastoid process of the temporal bone. It proceeds downwards along the nape of the neck, is attached to the spinous processes of all the vertebræ of the back, and the two lowest of the neck, and is also firmly connected by the intervention of a tendon to its fellow of the opposite side. It is inserted into the posterior part of the clavicle, the acromion, and almost all the spine of the scapula. It moves the scapula either obliquely upwards, directly backwards, or obliquely downwards, according as its different parts are called into action.

The latissimus dorsi arises, by a broad thin tendon, from the posterior part of the spine of the os ileum, from the spinous processes of the os sacrum, loins, and seven inferior of the back, and from three or four of the lower ribs; its fibres converging pass over the inferior angle of the scapula, are collected into a flat cord in the axilla, and inserted into the os humeri. Its action is to pull the arm downwards and backwards, and to roll the os humeri.

The second layer of muscles consists of three pair, two on the back and one on the neck. On the back are seated the serratus posticus inferior. This muscle originates from the spinous processes of the two inferior of the back and three superior vertebræ of the loins, is inserted into the four lowest ribs, which it draws downwards, and is therefore a muscle of expiration.

The rhomboideus proceeds from the spinous processes of the five superior vertebræ of the back and three inferior of the neck, and is inserted into the base

of

of the ſcapula, which it draws obliquely upwards, and directly inwards towards the ſpine.

On the neck is ſituated,

The ſplenius, which ariſes from the ſpinous proceſſes of the four upper vertebræ of the back and five lower of the neck; it is inſerted into the tranſverſe proceſſes of the five ſuperior vertebræ of the neck, the poſterior part of the maſtoid proceſs, and the os occipitis, where it joins the root of that proceſs. When one of theſe muſcles acts, it brings the head and neckly obliquely backwards, or, when they both act, they draw the head directly backwards.

The ſingle pair, which was mentioned, is the

Serratus poſticus ſuperior. This originates from the ſpinous proceſſes of the three loweſt vertebræ of the neck, and two uppermoſt of the back, and is inſerted into the ſecond, third, fourth, and fifth ribs. Its effect is to elevate the ribs, dilate the thorax, and conſequently it is ſubſervient to inſpiration.

Having removed theſe muſcles, we come to the third layer, which conſiſts of three on the back, and three on the neck.

On the back are,

The ſpinalis dorſi, which ariſes from the ſpinous proceſſes of the two uppermoſt vertebræ of the loins and three inferior of the back, and paſſes to the nine uppermoſt ſpinous proceſſes of the vertebræ of the back. The evident effect of this muſcle is to ſtraiten the ſpine, and prevent it from bending forwards.

The longiſſimus dorſi originates from the ſide of the os ſacrum, and its ſpinous proceſſes; from the poſterior ſpine of the ileum; from all the ſpinous proceſſes, and from the roots of the tranſverſe proceſſes of the vertebræ of the loins. It is inſerted into all the tranſverſe proceſſes of the vertebræ of the back,

and

and alſo into the lower edge of the ten uppermoſt ribs, near their tubercles. This muſcle ſtrengthens the ſpine, and keeps the body from bending forwards.

The ſacro-lumbalis, which ariſes in common with the longiſſimus dorſi, is inſerted into all the ribs near their angle. It pulls down the ribs, and aſſiſts in erecting the trunk of the body.

On the neck we find, the

Complexus, which ariſes from the tranſverſe proceſſes of the ſeven ſuperior vertebræ of the back and four inferior of the neck; it is inſerted, with the trapezius, into the inferior edge of the protuberance in the middle of the os occipitis, and into a part of the curved line which runs towards the maſtoid proceſs. When they both act, they draw the head directly backwards, or obliquely ſo when only one is called into action.

The trachelo-maſtoideus, which ariſes from the tranſverſe proceſſes of the three uppermoſt vertebræ of the back, and from the five lowermoſt of the neck, where it is connected to the tranſverſus cervicis, is inſerted into the poſterior part of the maſtoid proceſs. It aſſiſts the complexus, but pulls the head more to one ſide.

The levator ſcapulæ ariſes from the tranſverſe proceſſes of the five ſuperior vertebræ of the neck, and is inſerted into the ſuperior angle of the ſcapula. It elevates the ſcapula, and draws it a little forwards.

The fourth layer conſiſts of two pair on the back, two on the poſterior part of the neck, four ſmall pair, ſituated immediately below the poſterior part of the occiput, and three on the ſide of the neck.

On the back are the

Semi-

Semispinalis dorsi, which arises from the transverse processes of the seventh, eighth, ninth, and tenth vertebræ of the back, is inserted into the spinous processes of all the vertebræ of the back above the eighth, and into the two lowermost of the neck. Its effect is to extend the spine backwards.

The multifidus spinæ originates from the side and spinous processes of the os sacrum, and from the posterior part of the os ileum, where it joins the sacrum; from all the oblique and transverse processes of the vertebræ of the loins; from all the transverse processes of the vertebræ of the back, and from those of the neck, except the three upper; its tendinous and muscular fibres run in an oblique direction, and are inserted into the spinous processes of all the vertebræ of the loins, of the back, and of the neck, except the first. When one side of this muscle acts by itself it extends the spine obliquely, when both act they draw it directly backwards.

On the posterior part of the neck are the semispinalis colli, which arises from the transverse processes of the six uppermost vertebræ of the back, and is inserted into the spinous processes of all the vertebræ of the neck. It extends the neck backwards.

The transversalis colli, which proceeds from the transverse processes of the five uppermost vertebræ of the back, and is inserted into the transverse processes of all the cervical vertebræ, except the first and the last. It turns the neck obliquely backwards and a little to one side.

Below the posterior part of the occiput are,

The rectus capitis posticus major. This muscle arises from the external part of the spinous process of the second vertebra of the neck, ascends obliquely outwards, and is inserted into the os occipitis.

It

It pulls the head backwards, and assists a little in its rotation.

The rectus capitis posticus minor arises from a little protuberance in the middle of the back part of the first vertebra of the neck, and is inserted near the foramen magnum of the os occipitis. It assists in moving the head backwards.

The obliquus capitis superior arises from the transverse process of the first vertebra of the neck, and is inserted into the os occipitis. It draws the head backwards.

The obliquus capitis inferior arises from the spinous process of the second vertebra of the neck, and is inserted into the transverse process of the first vertebra of the neck. This muscle acts very powerfully in giving a rotatory motion to the head.

On the side of the neck are the scalenus anticus, which arises from the fourth, fifth, and sixth transverse processes of the vertebræ of the neck, and is inserted into the upper part of the first rib.

The scalenus medius, which proceeds from all the transverse processes of the vertebræ of the neck, and is inserted into the upper and outer part of the first rib.

The scalenus posticus, which arises from the fifth and sixth transverse processes of the vertebræ of the neck, and is inserted into the upper part of the second rib.

The effect of all the scaleni is to bend the neck to one side, or, when the neck is fixed, to raise the ribs and dilate the thorax.

There are a number of small muscles situated between the spinous and transverse processes of contiguous vertebræ, some of which approach so nearly to the nature of

of tendons as to ſerve merely as ligaments. The uſe of all theſe is to ſtrengthen and erect the ſpine.

In the deſcription which has been given of the muſcles which ſerve for the motion of the whole head, the reader cannot have failed to obſerve, how much more numerous thoſe are which are inſerted into the back part of the head, and pull it backwards, than thoſe which have the oppoſite inſertion and effect. The reaſon of this is, that the center of gravity of the head does not fall on the condyls, on which it is ſupported, but conſiderably farther forward; from which mechaniſm it is evident that the muſcles which pull the head back muſt be continually acted againſt. Hence, when a perſon falls aſleep, or is affected with the palſy, and the muſcles ceaſe to act, the head always falls forwards. By the ſpine being thus connected towards the poſterior part of the cranium, more ſpace is allowed for the cavities of the mouth and fauces.

Muſcles ſituated on the anterior part of the thorax.

After having removed the common integuments of the thorax, we obſerve a large muſcle, the pectoralis major, which riſes from the cartilaginous extremities of the fifth and ſixth ribs, from almoſt the whole length of the ſternum, and from near half the anterior part of the clavicle. Its fibres run towards the axilla, and it is inſerted into the upper and inner part of the os humeri. Its effect is to move the arm forwards and obliquely upwards towards the ſternum.

Having removed this we come to another layer, which conſiſts of three muſcles.

The ſubclavius is a ſmall muſcle which riſes from the firſt rib, and is inſerted into the inferior part of the clavicle. Its effect is to pull the clavicle downwards and forwards.

The pectoralis minor ariſes from the upper edge of the

the third, fourth, and fifth ribs, and is inserted into the coracoid process of the scapula. Its use is to bring the scapula downwards and forwards, or that being fixed, to pull the ribs upwards.

The serratus magnus originates from the nine superior ribs, by an equal number of fleshy points, resembling the teeth of a saw, whence the term serratus is derived. Passing over two angles of the scapula it is inserted into its base. Its effect is to move the scapula forwards, or when the scapula is forcibly raised, to draw the ribs upwards.

The muscles which cover the ribs being removed, we observe the space between the ribs filled up with double rows of muscles, called the intercostales externi and interni. The external arise from the inferior acute edge of each rib, and running obliquely forwards are inserted into the obtuse upper surface of the rib next below. The internal arise in the same manner as the external, except that, contrary to them, they begin at the sternum, and run obliquely backwards. The two rows of intercostals, therefore, decussate each other like the strokes of the letter X. The effect of the contraction of both series is the same, viz. that of bringing the ribs nearer to each other, and as each lower rib is more moveable than that above, to raise the ribs, dilate the thorax, and assist in inspiration.

Certain portions, both of the external and internal intercostals, are longer, and passing over one rib are inserted into the next below it. The ribs are likewise raised, and their posterior articulations strengthened, by twelve short muscles, which arise from eleven of the transverse processes of the dorsal vertebræ, and the lowest of those of the neck, and which are inserted into the rib immediately below the transverse process from which each of them rises.

The sterno-costalis arises from the cartilago ensiformis,

mis, and is inſerted into the lower edge of the cartilages of the third, fourth, and fifth ribs. Its effect is to depreſs theſe cartilages and the extremities of the ribs, to contract the cavity of the thorax, and therefore to aſſiſt in expiration.

The moſt important muſcle of the thorax, however, ſtill remains to be conſidered. The diaphragm is a broad and ſtrong muſcle, which divides the cavity of the abdomen from that of the thorax. It is placed very obliquely between theſe two cavities, its anterior connection being much higher than its poſterior. Its middle part is forced up by the viſcera of the abdomen, ſo as to form an arch. The diaphragm, at its anterior part, ariſes from the upper and internal part of the enſiform cartilage, and from the cartilages of the ſixth, ſeventh, and all the inferior ribs. The muſcular portions ariſing from all theſe points converge towards a common center, where they terminate in a broad triangular tendon. This being directed downwards and backwards is attached to a muſcular ſubſtance, which ariſes by eight heads from the ſecond, third, and fourth lumbar vertebræ. There are ſeveral paſſages through the diaphragm, which muſt not be paſſed over in ſilence. Among the muſcular portions which proceed frum the lumbar vertebræ, are openings through which paſs the aorta, the thoracic duct, the vena azygos, and the two great intercoſtal nerves. The muſcular fibres, which proceed from the lumbar vertebræ, run obliquely upwards and forwards, and form in the middle two fleſhy columns, which decuſſate, and leave an oval ſpace between them for the paſſage of the œſophagus and eighth pair of nerves. Towards the right ſide of the broad tendon, which forms the middle of the diaphragm, there is a large quadrangular opening, through which the vena cava paſſes to arrive at the

the heart. When the diaphragm contracts, its concavity is lessened, particularly on each side, over which the lungs are placed, its center being firmly fixed from its connection with the mediastinum. By the descent, however, of its sides, it pushes downwards and forwards the abdominal viscera, it lengthens, and of course enlarges, the cavity of the thorax, and is the principal muscle of inspiration. The ribs are at the same time raised by the intercostal muscles, by which the thorax is made wider. The chief muscles of expiration, on the other hand, are those which surround the abdomen. These counteract the intercostals, by pulling down the ribs, in which they are assisted by the serrati, and oppose the diaphragm by the postici inferiores pressing backwards and upwards the abdominal viscera. By these muscles respiration is in general carried on. In cases, however, of laborious respiration, whether from disease or violent exercise, other muscles are called into action; inspiration is then promoted by the pectoral muscles, the serrati antici majores, the serrati postici posteriores, and the scaleni. That these muscles may act with more advantage, persons labouring under difficult respiration extend and fix the neck, and raise the shoulders. In laborious expiration the quadrati lumborum, sacro-lumbales, and longissimi dorsi, concur in pulling down the ribs. The elasticity of the cartilages of the ribs is also on all occasions an agent in expiration.

The muscles situated on the anterior part of the abdomen are five pair. On the middle of the anterior part of the abdomen, three of its muscles, the two oblique and the transverse, terminate in tendinous substance, which forms an expansion the whole way from the cartilago ensiformis to the ossa pubis. This from its white appearance is called linea alba. The external layer is formed

formed by a mufcle, which from its fituation and the direction of its fibres is called the obliquus defcendens externus. This mufcle rifes by as many heads from eight or nine of the loweft ribs; its notches always mix with thofe of the ferratus major anticus, and generally adhere to the pectoralis major, intercoftals, and latiffimus dorfi. It proceeds obliquely downwards and forwards, and is attached partly to the linea alba and partly to the fpine of the ileum. Its tendinous fubftance, which forms part of the linea alba, divides below into two columns, which leave between them a flit named the ring of the abdomen; of thefe columns the inferior is inferted into the os pubis of the fame fide, the fuperior decuffates its fellow, and paffes over to be inferted into the os pubis of the other fide. That part of the external oblique mufcle, which is connected with the fpine of the ileum, is ftretched from the anterior fpinous procefs of that bone towards the os pubis, forming what is called Poupart's or Fallopius's ligament. This tendon is united with the ftrong tendinous expanfion of the thigh, called fafcia lata, which involves and fheaths the mufcles of the thigh, and, proceeding to the leg, performs there the fame office.

The opening, called the ring of the abdomen, formed by the tendons of this mufcle, gives paffage to the fpermatic veffels in men, and the round ligaments of the uterus in women. The contents of the abdomen, getting through this opening, form the inguinal hernia. Under Poupart's ligament pafs the great veffels of the thigh, and this is the feat of the crural or femoral hernia.—This mufcle affifts in the exclufion of the fæces and urine, and in expiration, and bends the body forwards.

The fecond layer is formed by the obliquus afcendens internus. This mufcle arifes from the fpinous and tranfverfe proceffes of the three uppermoft lumbar

 vertebræ,

vertebræ, from the upper part of the sacrum, and from the spine of the ileum, the whole length between the posterior and superior anterior spinous process. Passing obliquely upwards, it is inserted into the cartilaginous part of all the false ribs and the two lowest of the true, to the ensiform cartilage and to the sternum. At its anterior part it becomes tendinous, and dividing, receives the rectus muscle between its separate portions. Its posterior portion is connected with the tendon of the transversalis muscle, its anterior with the linea alba. At its lowest part it is inserted into the anterior part of the os pubis. Its use is to assist the former, but it bends the trunk in the reverse direction.

The transversalis has nearly the same origins as the internal oblique. It is inserted into the cartilago ensiformis above, and into the whole length of the linea alba, except at its lowermost part. It supports and compresses the abdominal viscera.

The rectus abdominis arises from the cartilago ensiformis and the cartilages of the three lowest true ribs. In its course downwards it passes through the sheath formed by the division of the tendon of the internal oblique, having the tendon of the external oblique without, and that of the transversalis within. The rectus is generally divided by three tendinous intersections. Below it is connected to the ossa pubis, where they are joined to each other. The use of this muscle is to compress the fore part, and more particularly the lower part of the abdomen. It also bends the trunk forwards, or raises the pelvis towards the sternum. By being surrounded by the tendons of other muscles, it is prevented from starting from its situation.

The pyramidales are a short pair of muscles, frequently wanting; they arise from the ossa pubis, and are inserted into the linea alba about half way between them and the navel. They assist the rectus.

The anterior part of the abdomen is distinguished into several divisions, called regions. 1. The epigastric region, which reaches from the pit of the stomach to within three fingers breadth of the navel, and is bounded laterally by the hypocondria. 2. The umbilical region, which extends three fingers breadth above and below the navel, and is terminated laterally by the lumbar regions; and 3. Below the umbilical region is the hypogastric, on each side of which are the iliac regions. Still lower down is the region of the pubis.

Within the cavity of the abdomen are situated four pair of muscles. The psoas magnus arises from the side of the body and transverse process of the lowest vertebra of the back, and from those of all the vertebræ of the loins. Passing downwards through the pelvis it is inserted partly into the lesser trochanter, and partly into that part of the os femoris a little below it. It raises the thigh forwards, or when the thigh is fixed, as in the posture of standing, it bends the trunk forwards on the ossa femoris. The psoas parvus proceeds from the two upper vertebræ of the loins, and sending off a small long tendon, is inserted into the brim of the pelvis at the junction of the os ileum and pubis. It assists the psoas magnus in bending the loins forwards.

The iliacus internus arises from the transverse process of the last vertebra of the loins, from the inner edge of the spine of the ileum, from the edge of that bone between its anterior spinous process and the acetabulum, and from most of the hollow part of the ileum. It joins with the psoas magnus, where it becomes tendinous, is inserted along with it into the smaller trochanter, and has the same effect.

The quadratus lumborum is seated further backward; it arises from the posterior part of the spine of

the ileum, and is inserted into the transverse processes of all the lumbar vertebræ, into the last rib near the spine, and by a small tendon into the side of the last vertebra of the back. Its use is to draw the loins to one side, or, when both act, to bend the loins forwards towards the ileum.

Within the pelvis are placed the obturator internus, which arises from the internal circumference of the foramen thyroideum. Its tendon passes out of the pelvis, between the posterior sacro-ischiatic ligament and the tuberosity of the os ischium, and is inserted into the large pit at the root of the trochanter major. Its effect is to roll the os femoris obliquely outwards.

The coccygeus passes from the spinous process of the ischium to the bottom of the os sacrum, and the whole length of the os coccygis. By its contraction the os coccygis is drawn forwards.

Belonging to the anus are,

The sphincter ani, which arises from the skin and fat which surrounds the verge of the anus. The fibres are gradually collected into an oval form, and surround the extremity of the rectum, which they serve to contract.

The levator ani arises from the os pubis, within the pelvis, and from the spinous process of the ischium. It is inserted into the sphincter ani, acceleratores urinæ, and the point of the os coccygis. It surrounds the extremity of the rectum and the neck of the bladder, so that joining with its fellow, they together very much resemble the shape of a funnel. It supports and draws upwards the rectum.

CHAP. XIII.

MUSCLES OF THE INFERIOR EXTREMITIES.

Mufcles of the Thigh.—Of the Leg.—Of the Foot and Toes.

AS the two fides of the trunk of the body correfpond, a defcription of one fide is to be underftood as applying equally to both. In the fame manner the parts of the extremities have their fellows on the oppofite fide.

The mufcles which belong to the thigh, and are fituated at the anterior part of the pelvis, are,

The pfoas magnus, } already defcribed.
The iliacus internus, }

The pectinalis arifes from the upper and anterior part of the os pubis, immediately above the foramen thyroideum. It is inferted into the anterior and upper part of the linea afpera of the os femoris, a little below the trochanter minor. Its ufe is to draw the thigh upwards and inwards, and to roll it in fome degree outwards.

The triceps adductor femoris arifes by three diftinct heads from the offa pubis, and is inferted into almoft the whole length of the linea afpera, into a ridge above the internal condyl of the os femoris and into the upper part of that condyl. The ufe of this extenfive mufcle is, as the name expreffes, to draw the thighs together; it alfo at the fame time tends to move them upwards and to roll the thigh outwards.

The obturator externus furrounds the foramen thyroideum, and alfo rifes from the membrane which fills up that foramen, and from the adjacent parts of the os

pubis and ischium. Its fibres converge to a point, and passing outwards around the back part of the neck of the os femoris, are inserted by a strong tendon into the inner and back part of the trochanter major, adhering in their course to the capsular ligament of the thigh bone. Its use is to roll the thigh bone obliquely outwards, and to prevent the capsular ligament from being pinched.

The muscles placed at the posterior part of the pelvis, and designed for the motions of the lower extremity are, the gluteus maximus, which forms the external layer, and arises from the posterior part of the spine of the ileum, from the whole posterior surface of the os sacrum, and from the posterior sacroischiatic ligament; descending obliquely, it passes over the trochanter major, is firmly connected to the tendinous expansions of the tensor vaginæ femoris, and is inserted by a broad tendon into the upper and outer part of the linea aspera. The effect of this muscle is to draw the thigh backwards and a little outwards.

The gluteus medius forms another layer. It arises from the anterior superior spinous process and the dorsum of the os ileum, and is inserted into the outer and posterior part of the trochanter major. Its use is to draw the thigh outwards, and a little backwards, and to roll it, especially when it is bended.

The third layer consists of four muscles.

The gluteus minimus arises from the outer surface of the os ileum and the border of the great niche. It is inserted into the upper and anterior part of the great trochanter, and assists the former muscle.

The pyriformis arises within the pelvis, from the anterior part of the os sacrum, thence becoming narrower, it passes out of the pelvis along with the posterior crural nerve, below the niche in the posterior part of the os ileum,

ileum. It is inſerted into a cavity at the root of the trochanter major. By its contraction it moves the thigh a little upwards, and rolls it outwards.

The gemini conſiſts of two portions, one of which riſes from the outer ſurface of the ſpine of the os iſchium, the other from the tuberoſity of the os iſchium and poſterior ſacro-iſchiatic ligament. It is inſerted into the ſame part of the trochanter major with the pyriformis and obturator internus. This muſcle rolls the thigh outwards, and confines the tendon of the obturator internus.

The quadratus femoris ariſes from the outſide of the tuberoſity of the os iſchium, is inſerted into a ridge which paſſes from one trochanter to the other, and rolls the thigh outwards.

The muſcles ſeated on the thigh, and which move the leg, conſiſt of two on the inſide, one on the outſide, four before, and four behind.

On the inſide are,

The ſartorius, which ariſes from the ſuperior anterior ſpinous proceſs of the ileum. This long muſcle, running downwards and a little inwards, is inſerted into the inner ſide of the tibia. It draws the legs obliquely inwards, ſo as to bring the legs acroſs each other, for which reaſon it is called the ſartorius, or the taylor's muſcle.

The gracilis ariſes near the ſymphyſis of the oſſa pubis, and is inſerted with the ſartorius into the inner part of the tibia. It aſſiſts the ſortorius in bringing the legs acroſs, and, when they are a little bent, to concur in bending them further.

On the outſide of the thigh is placed

The tenſor vaginæ femoris, which ariſes from the external part of the anterior ſuperior ſpinous proceſs of the os ileum. It is inſerted into the tendinous faſcia

which covers and confines the muscles of the thigh. Its use is to stretch and support the fascia, and also to roll the thigh somewhat inwards.

On the fore-part of the thigh are,

The rectus, which arises partly from the inferior and anterior spinous process of the ileum, and partly from the dorsum of the ileum, a little above the acetabulum. Passing down the middle of the os femoris it is inserted into the patella, by the intervention of which its effect, that of extending the leg, is much increased.

The vastus externus arises from the root of the trochanter major, and the outer edge of the linea aspera through its whole length. It is inserted partly into the upper and outer part of the patella, and partly into the tendinous expansion, which is continued from the outside of the thigh to that of the leg. This muscle assists the former in extending the leg.

The vastus internus arises from the fore part of the os femoris, the root of the trochanter minor, and inner edge of the linea aspera. It terminates partly in the tendinous aponeurosis of the leg, and is partly inserted into the inner and upper part of the patella. It also extends the leg.

The cruræus arises from the anterior part of the os femoris, between the two trochanters, but nearer the trochanter minor. It adheres firmly to the whole of the anterior part of the os femoris, is inserted into the middle of the patella, and assists in extending the leg.

On the posterior part of the thigh are placed

The semitendinosus, which arises from the tuberosity of the os ischium, and is inserted into the inside of the ridge of the tibia a little below its tubercle. Its effect is to bend the leg and draw it inwards.

The semimembranosus, which originates from the

tuberoſity of the iſchium, and is inſerted into the inner and back part of the head of the tibia. It bends the leg, and brings it directly backwards.

The biceps flexor cruris ariſes by two diſtinct heads. Of theſe the longer proceeds from the tuberoſity of the iſchium, and the ſhorter from the linea aſpera, a little below the termination of the gluteus maximus. The two heads join a little above the external condyl of the os femoris, and are inſerted by a ſtrong tendon into the head of the fibula, forming the external ham-ſtring. The internal is formed by the two preceding muſcles.

The popliteus ariſes from the lower and back part of the external condyl of the os femoris, it runs over the ligament which involves the joint, and is inſerted into a ridge at the upper and internal edge of the tibia, a little below its head. It aſſiſts in bending the leg, and prevents the capſular ligament from being pinched.

The muſcles ſituated on the leg, and which perform the motions of the foot, are either extenſors or flexors of the foot, or extenſors and flexors of the toes in general.

The extenſors of the foot are: the gaſtrocnemius, which ariſes by two heads, one from each of the condyls of the os femoris. A little below the joint their fleſhy bellies unite in a middle tendon, and below the middle of the tibia it terminates in a broad tendon of the following muſcle.

The ſoleus, or gaſtrocnemius internus, alſo ariſes by two heads; one from the upper and back part of the head of the fibula, the other from the upper and poſterior part of the tibia. The fleſh of this muſcle, covered by the tendon of the gemellus, runs down nearly as far as the extremity of the tibia, a little above which the tendons of this and of the preceding muſcle unite, forming a

ſtrong

ſtrong cord called tendo achillis, which is inſerted into the poſterior and projecting part of the os calcis. The diſtance of the extremity of the os calcis from the aſtragalus, which is the center, on which the motions of the foot are performed, gives theſe muſcles great power. Their effect is to extend the foot by bringing it more nearly into the direction of the tibia. When the foot, however, becomes the more fixed point, as in the erect poſture of the body, theſe two muſcles, by preſſing the foot againſt the ground, raiſe the body; they are therefore very much employed in walking, running, and jumping, but particularly in aſcending ſteps, whence the fatigue felt in theſe muſcles which form the calves of the legs by a continuance of that exerciſe.

The plantaris ariſes from the upper and back part of the external condyl of the os femoris, adhering in its deſcent to the capſular ligament of the knee. Paſſing under the gemellus, it ſoon terminates in a thin tendon, which is the longeſt in the body, and which is inſerted into the inſide of the back part of the os calcis. It co-operates with the former muſcle in extending the foot, and alſo pulls the capſular ligament of the knee from between the bones, and prevents it from being pinched.

The flexors of the foot are four, two of which belong to the tibia and two to the fibula.

The tibialis anticus proceeds from the upper and fore part of the tibia, and from the interoſſeus ligament. Near the extremity of the tibia it ſends off a round tendon, which paſſes under the ligamentum tarſi annulare near the inner ankle. It is inſerted into the inſide of the os cuneiforme internum and the poſterior end of the metacarpal bone, which ſuſtains the great toe. The effect of this muſcle is to bend the

foot,

foot, by drawing it upwards, and at the same time to turn it inwards.

The tibialis posticus proceeds from the upper part of the tibia near its union with the fibula, then passing through a perforation in the interosseous ligament, it continues its origin from the interosseous ligament, and from the upper half of the tibia, receiving also a few fibres from the fibula. It sends off a round tendon, which passes in a groove behind the malleolus internus. It is inserted into the inner part of the os naviculare, and into the adjacent bones, at the internal and upper part of the foot. This muscle also bends the foot, and turns it inwards.

The two flexors which proceed from the fibula, are,

The peroneus longus, which arises from the fore-part of the head of the fibula or *perone*, and also continues to receive fibres from the external part of this bone almost as low as the ankle. Its tendon runs in a channel at the back part of the outer ankle, thence being reflected to the sinuosity of the os calcis, it runs in a groove in the os cuboides, and passing close to the bones in the sole of the foot, it is inserted chiefly into the metatarsal bone of the great toe. This muscle moves the foot outwards and a little upwards.

The peroneus brevis arises from the outer and fore part of the fibula. Its tendon passes behind the outer ankle, in which situation it is retained by the same ligament as that of the last muscle. It is inserted into the root and external part of the metatarsal bone of the little toe. This muscle also moves the foot outwards and a little upwards.

The common extensors of the toes are,

The extensor longus digitorum pedis, which arises from the upper, outer, and fore part of the tibia,

interosseous

interosseous ligament, and inner edge of the fibula. It divides into four tendons under the ligamentum tarsi annulare. It is inserted by four flat tendons into the roots of the first joints of the four small toes. Its use is to extend all the joints of these toes. A portion of this muscle is inserted into the metatarsal bone of the little toe, assists in bending the foot, and is called the peroneus tertius.

The extensor brevis digitorum pedis arises from the fore and upper part of the os calcis, is inserted into the tendinous expansion at the upper part of the foot, and extends the toes.

The common flexors of the toes are,

The flexor brevis digitorum pedis, which arises from the lower part of the os calcis. Its thick fleshy belly soon divides into four tendons, which, after being pierced by those of the following muscle, are inserted into the second phalanx of the four small toes. This muscle bends the second joint of these toes.

The flexor longus digitorum pedis arises from the upper and back part of the tibia, some distance below its head. In its course downwards it is increased by fleshy fibres from the inner edge of the tibia, and by means of tendinous fibres is connected to the outer edge of that bone. Passing under two annular ligaments, which retain its tendon in its proper situation, it is received into a sinuosity at the inside of the os calcis, and about the middle of the sole of the foot divides into four tendons, which perforate those of the flexor brevis, and are inserted into the extremity of the last joint of the four small toes. Its use is to bend the last joint of the toes.

This muscle receives, in the sole of the foot, another, which arises from the inside of the os calcis, and which increases its strength.

The

The lumbricales pedis are four ſmall muſcles in the ſole of the foot, ſo called from their reſemblance in ſize and appearance to earth-worms: they ariſe from the four tendons of the flexor digitorum longus, and are inſerted into the inſide of the firſt joint of the four ſmall toes. Theſe muſcles render the flexion of the toes more extenſive, and draw them inwards.

The muſcles ſituated chiefly on the foot are thoſe deſigned for the motions of each of the toes in particular. To the great toe belong five muſcles. Of theſe, one extends it, two bend it, one draws it outwards, and another inwards.

The little toe, beſides the common flexors and extenſors, has two muſcles proper to itſelf. One of theſe draws it outwards, and the other contributes to its flexion.

Between the metatarſal bones are alſo ſeated ſeven muſcles, called the interoſſei interni et externi. The internal interoſſei are three in number; their uſe is to draw the three ſmaller toes towards the great toe. The external interoſſei are four; of theſe, the firſt ſerves to move the fore-toe towards the great-toe; the other three draw the three toes next the great toe outwards. All the interoſſei aſſiſt in extending the toes.

The tranſverſalis pedis ariſes from the under part of the anterior extremity of the metatarſal bone of the great toe, and terminates at that of the metatarſal bone of the little toe. By the contraction of this muſcle the great and little toes are brought nearer.

The muſcles ſituated in the foot are covered and protected by a ſtrong tendinous expanſion, which paſſes from the os calcis to the firſt joints of all the toes.

CHAP. XIV.

MUSCLES OF THE SUPERIOR EXTREMITIES.

Scapular Mufcles.—Mufcles of the Fore-arm.—Of the Hand.—Of the Fingers.

THE pectoralis major and latiffimus dorfi have already been defcribed.

The mufcles which are feated on the fcapula, and which are inferted into the os humeri, are,

The fupraſpinatus, which arifes, as its name expreffes, from that part of the fcapula which is above its fpine; it paffes under the acromion, adhering to the capfular ligament of the os humeri, and is inferted into the large tuberofity on the head of that bone. Its ufe is to raife the arm upwards, and to draw the capfular ligament from between the bones, fo that it may not be hurt by compreffion.

The infrafpinatus, which originates from all that part of the bafe of the fcapula that is between its fpine and inferior angle; and alfo from the fpine as far as the cervix fcapulæ. Its tendon, running forwards, is connected with the capfular ligament, and terminates in the middle and upper part of the protuberance on the head of the os humeri. This mufcle rolls the humerus outwards, fupports the arm when raifed, and alfo affifts in raifing it, and pulls the ligament from between the bones.

The teres minor arifes from the inferior cofta of the fcapula, and is inferted into the back part of the tuberofity on the head of the os humeri. Its ufe is to roll the humerus outwards and draw it backwards, and by

by its connection with the capsular ligament of the os humeri, to draw it from berween the bones.

The teres major arises from the inferior angle and inferior costa of the scapula; its fleshy fibres are continued over part of the infraspinatus muscle, to which they firmly adhere. It is inserted, by a broad and thin tendon, along with the latissimus dorsi, into the ridge at the inner side of the groove for lodging the tendon of the long head of the biceps. Its effect is to roll the humerus inwards, and draw it backwards and downwards.

The deltoides arises from the clavicle, processus acromion, and the spine of the scapula; from these origins its fasciculi converge, forming a covering to the anterior part of the joint of the os humeri. It is inserted into a rough protuberance in the outer side of the os humeri. The chief effect of this muscle is to raise the arm; but from the different direction of its fibres, it may also move it backwards or forwards.

The coraco-brachialis arises from the fore part of the coracoid process of the scapula, is inserted into the middle and inner side of the os humeri, and moves the arm upwards and forwards.

The subscapularis arises from the whole internal surface of the scapula; after being attached to the capsular ligament, it is inserted into the upper part of the small internal protuberance at the head of the os humeri. It rolls the os humeri inwards, draws it to the side of the body, and draws the capsular ligament from between the bones.

The muscles situated on the os humeri, and which move the fore-arm, are only four; two being placed before for the flexion of the joint, and two behind for its extension. Those placed before are,

The biceps flexor cubiti, which consists of two heads, which unite about the middle of the os humeri. Of these

these the shorter rises from the coracoid process of the scapula; the longer and outermost begins from the upper edge of the glenoid cavity of the scapula, passes over the head of the os humeri within the joint, and in its descent without the joint is inclosed, by a membranous ligament, in a groove near the head of the os humeri. This muscle is inserted, by a strong roundish tendon, into the tubercle on the upper end of the radius internally. Its effects are to bend the fore-arm, and to turn the radius outwards, and so bring the palm of the hand uppermost. Part of the tendon proceeding from this muscle is also spent in a tendinous expansion, which covers all the muscles at the inside of the fore arm, and joins with another tendinous membrane, which is sent off behind from the triceps extensor cubiti. The use of these expansions, as in other parts of the body, is to confine the motions of the muscles, to protect them, and to give origin to a number of fibres.

The brachialis internus arises from the os humeri at each side of the insertion of the tendon of the deltoides. Being closely applied to the inferior and inner part of the os humeri, it runs over the joint, is firmly attached to the ligament, and is inserted into the coronoid process of the ulna. It assists the former muscle in bending the fore-arm.

Behind are

The triceps extensor cubiti, which consists of three heads; of these one proceeds from the inferior costa of the scapula, another from the upper and outer part of the os humeri, and the third from the back part of that bone. These three heads, when united, form a large muscle, which is closely applied to the posterior part of the humerus, from which they receive some

muſcular fibres. This muſcle is fixed to the upper and outer part of the olecranon of the ulna.

The anconeus ariſes from the external condyle of the os humeri, and is inſerted into a ridge on the outer and poſterior edge of the ulna. It aſſiſts in extending the fore-arm.

The muſcles ſituated on the fore-arm may be divided into four orders: 1. Flexors and extenſors of the whole hand. 2. Flexors and extenſors of the fingers. 3. Supinators and pronators, or thoſe which roll the radius on the ulna. 4. Flexors and extenſors of the thumb and fore-finger.

The firſt order conſiſts of three flexors and three extenſors. The flexors are,

The palmaris longus, which ariſes from the inner condyle of the os humeri, and is inſerted partly into the annular ligament, which confines the tendons ſeated in the wriſt, and partly into the tendinous expanſion, which covers the palm of the hand. This muſcle bends the wriſt and ſtretches this membrane.

The palmaris brevis, which originates from the annular ligament and tendinous expanſion on the palm of the hand, and is inſerted into the os piſiforme, and the ſkin covering the abductor minimi digiti. It aſſiſts in contracting the palm of the hand. This ſmall muſcle is commonly conſidered as belonging to the former.

The flexor carpi radialis proceeds from the inner condyle of the os humeri, and is inſerted into the metacarpal bone of the fore-finger. It bends the hand and aſſiſts in its pronation, that is, in turning the palm downwards.

The flexor carpi ulnaris ariſes alſo from the internal condyle of the os humeri, and alſo from the outer ſide of the olecranon. It is inſerted into the os piſiforme, and aſſiſts in bending the wriſt.

 The

The extensors of the whole hand are,

The extensor carpi radialis longior, which arises from the lower part of the external ridge of the os humeri, above its external condyle. It is inserted into the upper part of the metacarpal bone, which supports the fore-finger. Its effect is to extend the wrist and draw the hand backwards.

The extensor carpi radialis brevior arises from the outer part of the external condyle of the humerus, and from the ligament which connects the radius to it. It is inserted into the upper part of the metacarpal bone of the middle finger, and extends the wrist.

The extensor carpi ulnaris arises from the external condyle of the os humeri, and also receives an accession of fibres in its progress from the ulna. Its round tendon is confined by a membranous sheath in a groove, which is situated at the extremity of the ulna. It is inserted into the upper part of the metacarpal bone of the little finger, and assists in extending the wrist.

The flexors and extensors of the four fingers are,

The flexor sublimis perforatus, which arises from the internal condyle of the os humeri, the inner edge of the coronoid process of the ulna, and the upper and anterior part of the radius. It sends off four tendons before it passes under the ligament of the wrist, which being divided for the passage of the tendons of the following muscle, are inserted into the anterior and upper part of the second bone of each finger. It bends the second joints of the fingers.

The flexor profundus perforans, which originates from the upper part of the ulna, and from a considerable part of the interosseous ligament. It divides into four tendons, which pass through the slits in the tendons of the preceding muscle, and are inserted into the up-

per part of the laſt bone of the four fingers. Its uſe is to bend the laſt joint of the fingers.

The lumbricales ariſe from the four tendons of the preceding muſcle, and are inſerted into the outer ſides of the broad tendons of the interoſſei muſcles. They increaſe the flexion of the fingers.

The extenſor digitorum communis ariſes from the outer condyle of the os humeri, and is inſerted into the poſterior part of all the fingers by a tendinous expanſion. It extends all the fingers.

The muſcles, which roll the radius on the ulna, are,

The ſupinator radii longus, which ariſes from the external ridge of the os humeri above the external condyle. It is inſerted into the outer ſide of the inferior extremity of the radius. Its effect is to roll the radius outwards, and conſequently to turn the palm of the hand upwards.

The ſupinator radii brevis, which ariſes from the external condyle of the os humeri, and poſterior ſurface and outer edge of the ulna. It is inſerted into the head, neck, and tubercle of the radius. It rolls the radius outwards, and turns the palm of the hand upwards.

The pronator radii teres, which originates from the internal condyle of the os humeri and coronoid proceſs of the ulna. It is inſerted into the poſterior part of the radius, about the middle of that bone. Its effect is to roll the radius, with the hand, inwards, and conſequently to turn the back of the hand upwards, or to lay the hand prone.

The pronator radii quadratus ariſes from the inner and lower part of the ulna. Its fibres, running tranſverſely, are inſerted into the anterior part of the radius oppoſite to their origin.

For the motion of the thumb are placed in the fore-arm,

The flexor longus pollicis manus, which originates from the upper and fore part of the radius; its tendon passes under the ligament of the wrist, and is inserted into the last joint of the thumb, which it serves to bend.

The extensor ossis metacarpi pollicis manus, which arises from the middle and posterior part of the ulna, from the middle and posterior part of the radius, and from the interosseous ligament. It is inserted into the os trapezium and upper back part of the metacarpal bone of the thumb. Its effect is to extend the metacarpal bone of the thumb outwardly.

The extensor primi internodii arises from the posterior part of the ulna, and from the interosseous ligament. It is inserted into the posterior part of the first bone of the thumb, which it extends obliquely outwards.

The extensor secundi internodii, arises from the middle and back part of the ulna, and from the interosseous ligament, and is inserted into the last bone of the thumb, which it extends obliquely backwards.

To the fore-finger belongs

The indicator, which begins from the posterior part of the ulna, about the middle of that bone. Its tendon, accompanying that of the extensor digitorum communis, which belongs to the same finger, they are inserted together into its upper part. Its effect is to extend the fore-finger, whence its name of *indicator*, as that is the finger with which we usually point at any object of attention.

The muscles seated in the hand may be divided into those of the thumb and those of the fore and little fingers.

The flexor brevis pollicis manus arises from the os trapezoides, annular ligament, os magnum, and os unciforme, and is inserted into the second joint of the thumb, which it serves to bend.

The

The flexor offis metacarpi pollicis, or opponens pollicis, arifes from the os trapezium and ligamentum carpi annulare. It is inferted into the under and anterior part of the firft bone of the thumb. Its effect is to bring the thumb inwards, fo as to place it in oppofition to the fingers.

The abductor pollicis manus commences from the ligamentum carpi annulare and from the os trapezium, and is inferted into the outer fide of the root of the firft bone of the thumb. Its ufe is to draw the thumb from the fingers.

The adductor pollicis manus arifes from the metacarpal bone which fuftains the middle finger, and is inferted into the inner part of the root of the firft bone of the thumb. This mufcle pulls the thumb towards the fingers.

The thumb has, therefore, in all, eight mufcles, four feated in the fore-arm and four in the hand. Of the whole eight, three are flexors, three extenfors, one is an abductor, the other an adductor.

One mufcle, the indicator, proper to the fore-finger, and feated in the fore-arm, has been already defcribed; another mufcle proper to this finger is feated in the hand; it is called

The abductor indicis manus, and arifes from the inner fide of the firft bone of the thumb and from the os trapezium, and is inferted into the firft bone of the fore-finger. It ferves to bring the fore-finger towards the thumb.

To the little finger belong

The abductor minimi digiti, which arifes from the os pififorme and the adjacent part of the annular ligament. It is inferted into the fide of the firft bone of the little finger, which it draws from the reft.

The adductor metacarpi minimi digiti manus, which arises from the os unciforme and the adjacent part of the annular ligament; it is inserted into the anterior part of the metacarpal bone of the little finger, which it draws towards the rest.

The flexor parvus minimi digiti arises from the os unciforme, and from the ligament of the wrist near it, and is inserted into the first bone of the little finger. It bends the little finger, and assists the adductor.

Between the metacarpal bones there are four internal and three external muscles, named interossei. They are inserted into the roots of the fingers. The interossei interni extend the fingers, and move them towards the thumb, except the third, which draws the middle finger from the thumb. The interossei externi also extend the fingers; but the first draws the middle finger inwards, the second draws it outwards, and the third draws the ring-finger inwards.

The figure in Plate IV. represents the first layer of muscles situated on the anterior part of the whole body, immediately under the common integuments, and tendinous fasciæ.

MUSCLES *situated on the* HEAD *and* NECK.

a, The anterior fleshy belly of the occipito-frontalis situated on the os frontis.

Above *a*, the tendinous aponeurosis of the occipito-frontalis, covering the upper part of the parietal bones.

b, Attollens aurem.

Under it the tendinous aponeurosis covering the temporal muscle.

Anterior auris between *c* and the ear.

c, Orbicularis palpebrarum.

Its

Its tendon is seen at the inner canthus, fixed to the nasal process of the superior maxillary bone.

Levator labii superioris alæque nasi.

Seen divided into two portions running down along the side of the nose; and on the outside of it, the levator anguli oris.

Next this, the

Zygomaticus minor.

Farther outwards,

Zygomaticus major.

On the ala and tip of the nose, the

Compressor naris.

d, Depressor anguli oris.

And beneath it, a portion of the depressor labii inferioris.

e, Orbicularis oris.

f, Platysma-myoides.

Behind *f*, the sterno-cleido-mastoideus is seen through the platysma-myoides.

TRUNK.

a, Pectoralis major.

The upper part of it is covered by the origin of the platysma-myoides.

b, Serratus magnus.

The other portions resemble this.

c, Latissimus dorsi.

d, Obliquus externus descendens.

e, Linea semilunaris.

f, Linea alba.

Below *f*, the umbilicus.

Between *e* and *f*, the rectus abdominis; and, at the inferior part of the linea alba, opposite to *g*, the pyramidales appear through the tendons of the oblique muscles.

g, Ring of the external oblique muſcle; with the ſpermatic chord, paſſing through it, and covered by the cremaſter muſcle.

Superior Extremity.

a, Deltoides.

Above the clavicle, a portion of the trapezius is ſeen.

b, Biceps flexor cubiti.

At the bending of the arm is ſeen its tendon going towards the radius, and the part, from which the tendinous aponeuroſis that covers the fore-arm, is cut off.

On the inſide of the biceps, part of the triceps extenſor cubiti; and on the outſide, part of the brachialis internus.

c, Supinator radii longus.

d, Pronator teres.

e, Palmaris longus.

f, Palmaris brevis.

On the palm of the hand, the aponeuroſis palmaris is ſeen extended from the annular ligament at the wriſt, to the roots of the metacarpal bones of the four fingers.

g, Flexor carpi radialis.

h, Part of the flexor ſublimis perforatus.

i, Inſertion of the flexor carpi ulnaris.

k, Abductor pollicis.

Inferior Extremity.

a, Tenſor vaginæ femoris, the vagina or tendinous faſcia being cut off.

On the outſide of it a portion of the glutæus maximus.

b, Part of the iliacus internus.

On the inſide of it, between *b* and *c*, part of the pſoas magnus.

c, Pectinalis.

d, Triceps

d, Triceps longus.

e, Gracilis.

f, Sartorius.

g, Rectus cruris.

Its tendon is ſeen inſerted into the patella, from which a ſtrong tendon is ſent to be fixed to the tubercle of the tibia.

h, Vaſtus externus.

i, Vaſtus internus.

k, Tibialis anticus.

l, Peroneus longus.

On the outſide of it, a portion of the ſolæus.

m, Extenſor longus digitorum pedis, with the peronæus tertius, and extenſor proprius pollicis pedis.

n, Gaſtrocnemius externus, or gemellus.

o, Soleus.

p, Ligamentum tarſi annulare.

q, Abductor pollicis pedis.

The figure in Plate V. repreſents the ſecond layer of muſcles on the anterior part of the whole body.

MUSCLES *ſituated on the* HEAD *and* NECK.

a, Corrugator ſupercilii.

b, Temporalis.

c, Maſſeter.

d, Levator anguli oris.

e, Buccinator.

f, Orbicularis oris.

Oppoſite to the right ala naſi, the portion of this muſcle, which Albinus names

Naſalis labii ſuperioris.

g, Depreſſor labii inferioris.

h, Sterno-cleido-maſtoideus, which is

Seen below, ariſing from the ſternum and clavicle, by two heads.

i, Sterno-hyoideus.

On the outſide of it, the

Omo-hyoideus.

Further out, a portion of the

Hyo-thyroideus.

k, Levator ſcapulæ.

TRUNK.

a, Subclavius.

b, Pectoralis minor.

c, Serratus magnus.

d, Rectus abdominis, divided into ſeveral fleſhy portions by its tendinous interſections.

e, Pyramidalis.

f, Obliquus aſcendens internus.

g, Spermatic chord, with the origin of the cremaſter muſcle.

SUPERIOR EXTREMITY.

a, Biceps flexor cubiti.

b, Short head of the biceps.

Beneath the upper part of it, a portion of the coracobrachialis.

Beneath the under part, a portion of the brachialis internus.

c, Long head of the biceps.

At the bending of the arm, the tendon of the biceps, and the place where the tendinous aponeuroſis was cut from it, are ſeen.

d, Extenſor carpi radialis longior.

Beneath it a portion of the

Extenſor carpi radialis brevior.

e, Flexor ſublimis perforatus.

f, Inſertion of the extenſor carpi ulnaris.

g, Extenſors of the thumb.

h, Op-

b, Opponens pollicis.
On the inside of it, a portion of the
Flexor pollicis brevis.
i, Tendon of the flexor longus pollicis manus, after passing through the flexor brevis pollicis manus.
k, Abductor minimi digiti manus.
l, Flexor parvus minimi digiti manus.
m, Ligamentum carpi annulare.

Inferior Extremity.

a, Iliacus internus.
Between *a* and *b*, part of the psoas magnus.
b, Pectinalis.
c, Triceps longus.
d, Gracilis.
e, Rectus cruris cut off near its origin.
f, Tendon of the rectus cruris cut off above the patella, from which a strong tendon is sent to be inserted into a tubercle of the tibia.
g, Portion of the gluteus medius.
On the inside of it, part of the gluteus minimus.
h, Vastus internus.
i, Vastus externus.
k, Cruræus.
l, Insertion of the biceps flexor cruris into the fibula.
m, Tendons of the gracilis and semitendinosus inserted into the tibia.
n, Soleus.
o, Peronæus longus.
p, Extensor longus digitorum, with the peronæus tertius on the outside, and extensor pollicis proprius on the inside.
q, Soleus.
r, Flexor longus digitorum.

s, Tendons

s, Tendons of the tibialis poſticus and flexor longus digitorum pedis.

t, Flexor brevis digitorum pedis.

The figure in Plate VI. repreſents the third layer of muſcles, with ſome of the ligaments, cartilages, and naked bones on the anterior part of the whole body.

a, Depreſſor labii ſuperioris alæque naſi.

b, Orbicularis oris, after moſt of the muſcles, which are fixed to it, and aſſiſt to form it, have been taken away.

c, Buccinator.

Above *c*, part of the pterygoidæus externus is ſeen paſſing behind the coronoid proceſs of the lower jaw.

d, Levator labii inferioris.

e, Sterno-thyroidæus.

Immediately above, and ſeemingly the continuation of it, the

Hyo-thyroidæus.

f, Scalenus anticus.

Contiguous to it, on the inſide, the

Scalenus medius.

Above it, a portion of the

Trachelo-maſtoidæus.

Between the ſcalenus anticus, and ſterno-thyroideus, and hyo-thyroidæus, the

Rectus capitis anterius major, and

Longus colli.

TRUNK.

a, Third row of external intercoſtal muſcles.

The reſt appear in the ſame manner between the other ribs.

b, Third

b, Third row of internal intercoſtal muſcles.
The reſt appear between the other ribs.

c, Tranſverſalis abdominis.

d, The place from which the inferior part of the tendon of the tranſverſalis, that paſſes before the rectus and pyramidalis muſcles, is cut off.

Between theſe portions of each ſide, the peritonæum is laid bare, and the ligaments of the bladder, which were formerly the umbilical arteries and urachus.

Between this portion and the os pubis, the ſpermatic chord is ſeen cut.

e, The inferior edge of the upper part of the tendon of the tranſverſalis, which paſſes behind the rectus, and immediately adheres to the peritonæum.

f, The anterior lamella of the internal oblique, which joined the tendon of the external to paſs over the rectus.

Between *f* and *g*, the poſterior lamella of the internal oblique, joining with the tendon of the tranſverſalis, to paſs behind the rectus.

g, The place at the linea alba, from which the tendon of the external oblique, and anterior lamella of the internal, were cut off.

At *g*, Umbilicus.

Superior Extremity.

a, Subſcapularis.

b, Teres minor.

c, Coraco-brachialis.

The part from which the ſhort head of the biceps flexor cubiti was cut off from it, is ſeen at its upper end.

d, Brachialis internus.

e, Brachialis externus, or third head of the triceps.

f, Extenſor

f, Extenſor carpi radialis longior, and with it the extenſor carpi radialis brevior.

Both theſe are diſtinctly ſeen in the right hand.

Between the tendon of the brachialis internus and extenſor radialis, the

Supinator radii brevis is ſeen.

g, Flexor longus pollicis manus, with the fleſhy portion of it which ariſes from the internal condyle of the os humeri.

h, Flexor profundus perforans, which ſplits into four tendons, which paſs under the ligamentum carpi annulare.

i, Pronator quadratus.

k, Adductor minimi digiti manus.

l, One of the lumbricales.

The other three appear in the ſame manner, along the tendons of the flexor profundus.

Behind theſe, the internal interoſſei are ſeen.

Inferior Extremity.

a, Glutæus minimus.

b, Iliacus internus.

On the inſide of it, between *b* and *c*, the pſoas magnus.

c, Obturator externus.

d, Adductor brevis femoris.

e, Adductor magnus femoris.

f, Gracilis; which is

Seen inſerted into the inſide of the head of the tibia.

g, The ſhort head of the biceps flexor cruris.

h, Peroneus longus.

i, Peroneus brevis.

Between theſe two peronei and tibia, the tibialis poſticus is ſeen.

k, Tendon

k, Tendon of the tibialis poſticus, covering the tendon, of the flexor longus digitorum pedis.

l, Extenſor brevis digitorum pedis.

The figure in Plate VII. repreſents a back view of the muſcles, which are immediately ſituated below the common integuments.

HEAD *and* NECK.

a, Part of the occipito-frontalis muſcle, with its aponeuroſis.

b, Attollens aurem.

c, Anterior auris.

d, Retrahentes auris.

TRUNK.

a, Trapezius, or cucularis.

b, Its tendinous edge joining with its fellow in the nape of the neck, which is called *ligamentum nuchæ* or *colli.*

c, The fleſhy belly of the latiſſimus dorſi.

d, The tendon of the latiſſimus dorſi, which ariſes in common with the ſerratus poſticus inferior.

e, Part of the obliquus externus abdominis.

SUPERIOR EXTREMITY.

a, Deltoides.

b, Infraſpinatus, with a portion of the teres minor and major below it.

c, Triceps extenſor cubiti.

Its tendon is ſeen inſerted into the head of the ulna, called *olecranon*; and, on the inſide of it, the *anconeus*.

d, Extenſor carpi radialis longior, covered by a portion of the ſupinator radii longus; and, under it, a portion of the extenſor carpi radialis brevior.

e, Extenſor digitorum communis manus, which ſplits into four tendons, and paſs with the indicator, under

under the ligamentum carpi annulare externum, at the extremities of the metacarpal bone, under ligaments proper to themſelves; and are loſt in a broad tendon, which covers the back of the four fingers.

f, Extenſor oſſis metacarpi pollicis manus.

g, Extenſor primi internodii pollicis manus.

h, Extenſor ſecundi internodii pollicis manus.

i, Extenſor carpi ulnaris.

k, Part of the flexor carpi ulnaris.

Under it, part of the

Flexor profundus perforatus.

And on the inſide, part of the

Flexor ſublimis perforatus, which is more diſtinctly ſeen on the right fore-arm. Likewiſe, on the right hand, are ſeen part of the abductor pollicis manus, abductor minimi digiti manus, and the aponeuroſis palmaris.

INFERIOR EXTREMITY.

a, Gluteus maximus.

b, Part of the gluteus medius.

c. Part of the tenſor vaginæ femoris.

d, Vaſtus externus.

e, The long head of the biceps flexor cruris:

And beneath it,

f, Part of the ſhort head.

g, Semitendinoſus:

And beneath it, on each ſide,

A portion of the ſemimembranoſus in ſeen.

h. Gracilis.

On the outſide of it,

A portion of the abductor magnus is ſeen.

i, A ſmall part of the vaſtus internus.

k, Gaſtrocnemius externus, or gemellus;

And

And within its outer head,

A portion of the plantaris.

l, Solæus or gastrocnemius internus.

m, Tendo Achillis, with the plantaris.

n, Peroneus longus.

o, Peroneus brevis; between it and the tendo Achillis, a portion of the flexor longus digitorum pedis.

p, Tendons of the extensor longus digitorum pedis, with the peroneus tertius, passing under the ligamentum tarsi annulare; and the flexor brevis digitorum pedis is seen beneath them.

q, Abductor minimi digiti pedis; and above it the tendons of the peroneus longus and brevis, passing under their own proper ligaments.

The figure in Plate VIII. represents the second layer of the muscles on the back-part of the body.

Head *and* Neck.

a, Temporalis; its tendon is seen passing below the zygoma.

b, Masseter.

c, Splenius capitis et colli.

d, Portion of the complexus.

e, Levator scapulæ, or the musculus patientiæ,

Trunk.

a, Rhomboides major.

b, Rhomboides minor:

And immediately above it, the upper edge of the serratus posticus superior is seen.

c, The serratus posticus superior on the right side.

d, Serratus posticus inferior.

e, Part of the spinalis dorsi,

f, Part of the longissimus dorsi.

g, Part of the sacro lumbalis.

h, Serratus magnus.

i, The broad tendon, by which the latiſſimus dorſi begins, and from which the tendon of the ſerratus poſticus inferior is inſeparable.

k, Part of the obliquus internus aſcendens abdominis.

l, The ſphincter ani, fixed to the point of the os coccygis; at the ſide of which the coccygæus, and a portion of the levator ani, are ſeen, &c.

Superior Extremity.

a, Supra-ſpinatus.

b, Infra-ſpinatus.

c, Teres minor.

d, Teres major.

e, Triceps extenſor cubiti.

f, Its head called *longus*.

g, The brevis: And,

h, A ſmall portion of the third head, named *brachialis externus*.

i, The tendon of the triceps, inſerted into the olecranon.

k, Part of the brachialis internus.

l, Anconæus, which ſeems to be continued from that part of the brachialis externus immediately above it.

m, Extenſor carpi radialis longior; and beneath it, the brevior: both are ſeen at the wriſt, inſerted into the metacarpal bones of the fore and middle fingers.

n, Flexor carpi ulnaris.

o, Part of the ſupinator radii brevis.

p, Extenſor oſſis metacarpi pollicis manus.

q, Extenſor primi internodii pollicis manus.

r, Extenſor ſecundi internodii pollicis manus.

ſ, Indi-

s, Indicator, inserted into the root of the first joint of the fore-finger.

t, One of the three external interossei manus. The other two are distinctly seen without letters.

u, One of the tendons of the extensors of the fingers cut; and the same is seen in each of the other three fingers, joining with the tendons and aponeuroses of the interossei and lumbricales, and spread upon the back of the fingers.

N. B. On the right hand, part of the flexors of the fingers, the abductor pollicis and minimi digiti, are seen.

INFERIOR EXTREMITY.

a, Glutæus medius.

b, Pyriformis.

c, The two muscles called *gemini*, between which the tendon and fleshy belly of the obturator internus passes over the tuberosity of the os ischium, are seen within the pelvis, partly covered by the coccygæus and levator ani.

d, Quadratus femoris.

e, Vastus externus.

f, *f*, Parts of the triceps magnus.

g, Long head of the triceps flexor cruris, and beneath it part of the short head is seen.

h, Semitendinosus, and beneath it parts of the semimembranosus are seen on each side of it.

i, Gracilis.

k, A small portion of the vastus internus.

l, Poplitæus.

m, The fleshy belly of the plantaris; and its long slender tendon is seen passing over the inside of the solæus.

n, Solæus.

o, The place where the tendon of the gemellus was cut off; but the fleſh of the ſolæus runs farther down.

p, Tendo Achillis, with the plantaris.

q, Peroneus longus, paſſing at the outer ancle to the ſole of the foot; beneath it, the peroneus brevis to the root of the metatarſal bone of the little toe; and, between it and the tendo Achillis, a portion of the flexor longus digitorum pedis.

r, Tendons of the extenſor longus digitorum pedis, with the peroneus tertius; and beneath theſe, the extenſor brevis digitorum pedis.

ſ, Flexor brevis minimi digiti pedis.

The figure in Plate IX. repreſents the third layer of muſcles on the poſterior part of the body, with ſome of the ligaments and naked bones.

MUSCLES *on the* HEAD *and* NECK.

a, Part of the buccinator.

b, Complexus.

c, Trachelo-maſtoideus; on the outſide of it, the tranſverſalis colli.

d, Scalenus medius.

e, Scalenus poſticus.

TRUNK.

a, Spinalis dorſi; and beneath it, the multifidus ſpinæ.

b, Longiſſimus dorſi, which ſends off a fleſhy ſlip to the trachelo-maſtoidæus.

c, Sacro lumbalis, with the cervicalis deſcendens ſent off from it along the ſide of the neck, and outſide of the tranſverſalis colli.

d, Semi-

d, Semispinalis dorsi.

e, Transversalis abdominis.

N. B. The spaces between the spinous processes of the vertebræ have muscular fasciculi between them, particularly those of the neck; and are named *interspinales colli*, *dorsi*, and *lumborum*; but those of the back seem to be tendinous and ligamentous.

SUPERIOR EXTREMITY.

a, Teres major.

b, Part of the coraco-brachialis.

c, Part of the brachialis internus.

d, The third head of the triceps extensor cubiti, called *brachialis externus*, after the longus and brevis have been cut off.

e, Extensor radialis longior.

f, Extensor radialis brevior.

g, Part of the flexor profundus perforans.

h, Supinator radii brevis.

i, Part of the adductor pollicis manus.

k, One of the three external interossei; the other two may be easily distinguished without letters.

l, Tendons of the extensors of the fingers, joining with those of the lumbricales and interossei, which form a tendinous expansion on the back of the four fingers.

N. B. On the right hand, part of the flexors of the fingers and thumb, part of the adductor pollicis, and the whole of the adductor minimi digiti, are seen.

INFERIOR EXTREMITY.

a, Glutæus minimus.

b, Obturator internus; its fleshy belly is seen within the pelvis.

Beneath *b*, the tendon of the obturator externus.

c, Semimembranosus.

d, The short head of the biceps flexor cruris.

e, Triceps magnus.

f, Gracilis.

In the ham, the origins of the two heads of the gastrocnemius externus and plantaris, are seen.

g, Poplitæus.

h, Tibialis posticus.

i, Flexor longus digitorum pedis.

k, Flexor pollicis longus.

l, Peroneus longus, running down to be inserted into the metatarsal bone of the little toe.

Beneath it, the peroneus brevis, passing to the sole of the foot.

m, Extensor brevis digitorum pedis.

n, Part of the flexor longus digitorum pedis.


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Chap. XV.

THE CELLULAR SUBSTANCE, FAT, AND INTEGUMENTS OF THE BODY.

General Deſcription of the Cellular Subſtance; its Uſes.—The Fat; its Uſes.—The Skin.—The Organ of Touch.—The Epidermis.—Cauſe of the black Colour of the Africans.—Corns.—Fontana's microſcopic Obſervations on the Epidermis.—Quantity of Perſpiration from the Human Body.

IN the preceding chapters the muſcles of the human body have been treated of as ſo many diſtinct and ſeparate maſſes of fleſh. It is neceſſary, however, to remark, that when the anatomiſt comes to trace them in the ſubject, he finds the caſe far otherwiſe, as moſt neighbouring muſcles are mixed and confuſed together by an intertexture of fibres, as well as by being involved in cellular ſubſtance.

The cellular ſubſtance is a looſe fibrous web, and when filled with air plainly exhibits its real ſtructure, viz. that of cells communicating with each other.

This ſubſtance forms a great part of the body, as it is interpoſed between all the muſcles, all the faſciculi of muſcular fibres, and it ſhould ſeem alſo, that it involves the ultimate fibres, of which theſe faſciculi are compoſed.

All the blood-veſſels alſo, and nerves, are in their courſe attached to the neighbouring parts by means of this ſubſtance. Many of the glands too, which are compoſed of ſmaller maſſes, are united into one body by its intervention. It ſeems probable, indeed, that the membranes which inveſt the contents of the abdomen and thorax, and other membranes in other

parts of the body, are composed of the cellular substance in a more consolidated state; and it is therefore very properly considered as an universal connecting medium in every part of the body.

The uses of this substance are so important, that, in all probability, animals could not exist without it. By uniting the fibres of the muscles into compact masses, it secures them from becoming entangled with each other, and with the minute blood-vessels, lymphatics and nerves, which are every where distributed among them. At the same time, however, that it connects together the muscles, and preserves them in their relative situations, it is sufficiently loose to give full play to all their motions. It serves also the purpose of a soft and compressible cushion, interposed among the muscles, and, being always moist and slippery, renders their motions easy, and prevents friction.

The cellular substance also affords a lodgment to the fat, and, together with it, fills up the interstices between muscles, and adds to the beauty, evenness, smoothness, and softness of the surface of the body.

The Abbè Fontana, on examining the fat of different animals, found it fluid and of an oily nature. It was contained in very minute vesicles heaped together, and these vesicles were covered with a thin tissue of twisting fibres. On pressing them, he plainly perceived the fat ooze out on all sides, but on the most careful examination was unable to discover any ducts going to or from them.

The uses of the fat, as has been already intimated, are in some respects similar to those of the cellular substance, in which it is seated. It involves many of the viscera, particularly those of the abdomen, and here it increases, in people disposed to obesity, to a great

great degree. Within the cranium, where by its preſſure it might injure the brain, none of this ſubſtance is found.

The cellular ſubſtance, beſides ſerving the purpoſes already mentioned, by being placed between the ſkin and the muſcles, is always conſidered as one of the integuments of the body. The other integuments are the ſkin, properly ſo called, and the epidermis or ſcarf ſkin.

The ſkin is probably nothing more than a condenſed cellular ſubſtance, copiouſly furniſhed with blood-veſſels, lymphatics, and nerves, as it within gradually becomes leſs denſe, and is at length inſenſibly loſt in the looſe cellular ſubſtance. It covers the whole ſurface of the body, is tough, elaſtic, and forms, by means of the nerves, which terminate in it, particularly at the extremities of the fingers, where it is moſt ſenſible, the organ of touch.

The cutis, when freed from the epidermis, which is its external covering, is found to be furniſhed with innumerable papillæ, which appear like minute granulations; their uſe is probably to increaſe the ſenſibility of the ſkin, as where it is moſt ſenſible they are moſt remarkable.

The ſkin or cutis, however, not only covers the outer parts of the body, but becoming thinner and more delicate enters and inveſts internally the various cavities which open on the ſurface. It is every where pierced with blood-veſſels, and in ſome parts with the ducts of ſmall glands, which are ſeated between the ſkin and the cellular ſubſtance, and which pour out an oily ſebacious matter for the lubrication of the ſurface of the body.

The epidermis or ſcarf ſkin every where covers the true ſkin, which would otherwiſe, from its extreme ſenſibility,

fensibility, occasion much uneasiness from the friction to which the surface of the body is necessarily exposed. The epidermis consists of a mucous substance, which is situated next the true skin, and a dry, transparent, and in some measure horny substance, which is external.

The mucous substance, called corpus mucosum, or rete Malpighianum, is of a consistence between that of a solid and a fluid, and is often treated of by anatomists as a distinct covering of the body. The colour of it varies according to the complexion. In fair people it is white, in brown people of a dusky hue, and in the Africans black. In the latter it is also more solid, and can be separated from the external part of the epidermis, which cannot be effected in Europeans. By friction, the epidermis gains very much in thickness, as may be observed in the hands of labouring people, and in the soles of the feet of those much accustomed to walking. Corns, which are nothing but hardened epidermis, are the consequence of the pressure and friction of tight shoes *.

The epidermis is not furnished either with nerves or blood-vessels, and is therefore insensible. The Abbè Fontana submitted some very minute portions of the epidermis, taken from his hand, to examination by a microscope which magnified seven hundred diameters. The epidermis appeared to be composed of winding cylinders, which approached each other, and retreated with much regularity and order; small globules also were in parts perceptible. When the

* The cure of these disagreeable excrescences is very obvious from this account; nothing is indeed required for this purpose, but to cover them with any soft adhesive substance, which will protect them from friction, when they will naturally decay, and in time come off spontaneously.

portion

portion of epidermis was covered with water, it appeared more tranſparent, and the cylinders and globules were ſeen more diſtinctly. He could obſerve nothing, however, like perforations or holes in the epidermis, and therefore doubts of their exiſtence. It ſeems probable, the Abbè Fontana adds, that the lymphatics, which le Pere della Torre pretends to have ſeen in the epidermis, were nothing but theſe winding cylinders.

We muſt believe, however, from the quantity of ſenſible and inſenſible perſpiration, eſpecially in warm climates, where, according to Sanctorius, who made his experiments in Italy, it amounts to five-eighths of the food taken in, that there are perforations in the epidermis for the paſſage of exhalent arteries. It may be alſo added, that the appearances exhibited by objects ſubmitted to microſcopes of high powers are never much to be depended on, and have given riſe to numerous deceptions.

Immediately below the ſkin of quadrupeds, except thoſe of the porcine (ſwine) ſpecies, lies a thin fleſhy expanſion, called panniculus carnoſus, covering the greater part of the body, and ſurrounding the other muſcles. In man there is nothing ſimilar to this, excepting the platiſma myoides, or the occipito-frontalis muſcle. The uſe of this thin muſcular expanſion is to wrinkle and move the ſkin in order to ſhake off duſt, inſects, &c.

Chap. XVI.

THE HAIR AND THE NAILS.

Opinions of Anatomiſts with reſpect to the Nature of the Hair, Nails, &c.—Hair originates from the Cellular Subſtance.—Fontana's Obſervations on Hair.—The Nails.—The Horns, Hoofs, and Claws of Animals.

MANY anatomiſts chuſe to call the hair, the nails, and the horns of animals, productions of the epidermis; by Malpighi and Ruſh the hairs were ſuppoſed to be continuations from the nerves; neither of which opinions, however, ſeems to be ſufficiently proved, though the former appears by far the more probable. The hairs are diſtributed more or leſs remarkably over the whole body, except on the palms of the hands and ſoles of the feet. They riſe each of them from a ſeparate oval bulb, placed beneath the true ſkin, and lodged in the cellular ſubſtance, and they are ſurrounded by a ſheath, which riſes with them as far as the ſurface of the body.

The Abbè Fontana took a hair, which he cleanſed by repeatedly drawing it through a piece of fine linen dipt in water; he examined it with lenſes of different powers, from ſome which magnified 400, to others which magnified 700 diameters, and the appearances, he informs us, were uniformly the ſame. The hair in general appeared of the colour of tranſparent amber; towards the center, however, of it, there was an obſcure line, which was broken at one part. It appeared woven, and formed by, or covered with, twiſting cylinders, interrupted at places, and winding like the inteſtines of animals. Among the winding

winding cylinders there appeared minute globules of the fame diameter with the cylinders. Having crufhed the hair at one of its extremities, it appeared as if formed of many irregular polifhed trunks, which were compofed of bundles of very fmall winding cylinders, with fome globules fcattered on the cylinders themfelves.

The nails are horny infenfible bodies, formed of thin lamellæ or plates. They rife by a fquare origin from the laft joints of the fingers and toes, and are hard where they are expofed to the air, but foft near their roots. The ftructure of the horns, hoofs, and claws of animals is very fimilar to that of our nails. A minute portion of a finger nail being fubmitted to the microfcope, exhibited the fame appearance as the epidermis. Both the nails and hair grow entirely from below, by a regular propulfion from their roots.

Chap. XVII.

THE CAVITY OF THE ABDOMEN.

Contents of the Abdomen.—Parts involved by the Peritoneum.—Parts not involved by it.—The Peritoneum.—The Mesentery.—The Omentum.—Different in Man and Quadrupeds.

THIS cavity is bounded above by the diaphragm, below by the bones of the pelvis, at the sides by various muscles and the false ribs, before by the muscles of the abdomen, and behind by the vertebræ of the loins and the os sacrum. Strictly speaking, however, no part is said to be within the cavity of the abdomen, which is not involved in a thin transparent membrane, called the peritoneum, of which a more particular description will presently be submitted to the reader.

The parts which are involved in the peritoneum are, the mesentery, the omentum or caul, the stomach, the small and great intestines, the lacteal vessels, the pancreas, the spleen, and the liver.

The organs which are not involved in the peritoneum, but are placed behind it, are the kidneys, the ureters, the receptacle of the chyle, the aorta, and the vena cava.

The upper part of the bladder is involved in the peritoneum, the lower is placed without it.

The peritoneum is to be considered as a membrane forming an internal covering to the parts which are the boundaries of the abdomen, and at the same time doubled back on itself in such a manner as to form the external covering of the abdominal viscera.

The internal surface of the peritoneum is smooth,

its external is rough, and united to the neighbouring muscles and vessels by the intervention of cellular substance. The cellular texture attached to the peritoneum, and in some parts included within its duplicatures, is generally replete with fat. The peritoneum is a dense but thin and transparent membrane, the uses of which are to retain the viscera of the abdomen in their places, and by the smooth and moist covering which it affords them, to prevent adhesions of one viscus to another; for which it is excellently adapted by being continually moistened by a serous fluid, which proceeds from very minute pores. The existence of these is proved by spreading a portion of the peritoneum on the end of the finger, and then pulling it very tight on all sides; by these means the pores are dilated, and small drops may be observed to proceed from them.

The mesentery is a production of the peritoneum, and is formed by two laminæ of this membrane, including cellular substance. It rises by a narrow origin from the first, second, and third vertebræ of the loins; it advances forwards, and gradually becomes broader in its progress. The mesentery at length embraces the intestines with its laminæ, and thus affords them the coat which they derive from the peritoneum. That part of the mesentery which involves the small intestines is more properly called the mesentery; that which involves the large is distinguished by the term mesocolon. The mesentery includes between its laminæ all the blood-vessels and nerves which belong to the intestines, and also the numerous lacteal vessels which take up the chyle from the intestines, and the glands with which these vessels are connected.

The omentum or caul is also formed by a dublicature of the peritoneum, including thin cellular substance,

with a large quantity of fat. It is variously attached to several of the viscera of the abdomen. The superior portion of it is divided into two borders, one of which is fixed to the arch of the colon, the other along the great curvature of the stomach. Below this it is loose, and is placed between the intestines and the anterior part of the peritoneum. Besides this large membranous covering, called the great omentum, there is a much smaller membrane of the same kind, which is called the little omentum. It is fixed by its whole circumference partly to the small curvature of the stomach, and partly to the concave side of the liver. The little omentum is thinner and more transparent than the other, but its structure is much the same, and it is in fact a continuation of the larger.

The omentum in man descends as far as the navel, in quadrupeds much lower. The reason for this difference seems to be, that from the erect posture of man, the oily matter exuded from the omentum must fall downwards to lubricate the intestines, which are placed still lower; this, however, cannot happen in quadrupeds, which have the trunk of the body in a horizontal situation, and therefore stand in need of a longer omentum; but as the use of the omentum is not fully ascertained, this explanation is perhaps imaginary.

CHAP. XVIII.

THE STOMACH AND INTESTINES.

General Deſcription of the Stomach.—Length of the Inteſtines in Man and Quadrupeds.—Small and large Inteſtines.

THE ſtomach is a membranous ſack, in form, when diſtended, not unlike a bag-pipe. The ſtomach is much larger towards the left ſide than towards the right. It has two orifices, one towards its left ſide, where the œſophagus or gullet enters, called the cardia, and another towards the right, called the pylorus, which opens into the inteſtines. The great extremity of the ſtomach is in the left hypochondrium, and for the moſt part immediately under the diaphragm, yet the left orifice is not in the left hypochondrium, but almoſt oppoſite to, and very near the middle of the bodies of the loweſt vertebræ of the back. The ſmall extremity of the ſtomach does not reach to the right hypochondrium; it bends obliquely backward towards the other orifice; ſo that the pylorus lies about two fingers breadth from the body of the vertebræ, immediately under the ſmall portion of the liver, and conſequently lower down and more forward than the cardia. The ſtomach is connected to the omentum, and by means of the omentum, on the left ſide, to the ſpleen.

The orifices of the ſtomach are placed in the receſſes on each ſide of the ſpine, and the body of the ſtomach is cloſely applied to it, and in a manner bent round it. The orifices of the ſtomach are therefore placed further back than its body, and are alſo a little higher, though

when the ſtomach is diſtended its body riſes nearly to a level with its orifices. The body of the ſtomach is diſtinguiſhed into two curvatures; the concave ſurface, which is applied round the ſpine, is called the leſſer curvature, and that which is convex, and is turned forwards and downwards, the greater.

The ſtomach is formed of four coats. The external of theſe is the peritoneal; the ſecond is muſcular, and is formed of fibres, which are continued from the muſcular coat of the œſophagus. Theſe fibres are variouſly diſtributed in the ſtomach. Some run directly in the leſſer curvature to the right orifice of the ſtomach, and are loſt in the duodenum; ſome run down each ſide of the ſtomach, and are loſt in its wideſt part towards the left ſide. Beſides theſe longitudinal fibres, the ſtomach is ſurrounded by ſome which are circular, and which are alſo continued from the œſophagus. There is a large aſſemblage of muſcular fibres round the right orifice of the ſtomach, which conſtringes it ſo as to prevent the food from paſſing into the inteſtines before it has undergone the proper changes in the ſtomach.

If we examine the inner ſurface of the ſmall extremity of the ſtomach, where it ends in the inteſtinal canal, we obſerve a circular border with a roundiſh hole in the middle, which is the pylorus, as before mentioned. The border is formed, partly by a fold of the internal coats of the ſtomach, and partly by a collection of fleſhy fibres fixed in the duplicature of the tunica celluloſa, and diſtinguiſhed from the other muſcular fibres by a thin whitiſh circle, which appears even through the external coat, round the union of the ſtomach and inteſtines.

The third coat of the ſtomach, which conſtitutes the greateſt part of its ſubſtance, is the cellular, or, as it has

has been improperly called, nervous coat. This is thick, firm, of a white colour, and is connected to the muſcular by the intervention of cellular ſubſtance, as it is alſo to the coat within.

The fourth and inner coat of the ſtomach is the villous. This and the cellular coat, being more extenſive than the reſt, are formed into numerous wrinkles or folds. It obtains the name of *villous* from the unevenneſs of its ſurface, as being ſimilar to wool or hair when immerſed in water. It is ſingle, of a red colour, and is copiouſly ſupplied with mucus.

The ſtomach is furniſhed with lacteals, which riſe moſt numerouſly from it near its right orifice; it is alſo very copiouſly furniſhed with nerves and blood-veſſels, which will be more fully deſcribed hereafter. With reſpect to the uſes of the ſtomach, they will be ſpoken of at large in the chapter on digeſtion.

By the inteſtines is meant the whole of the alimentary tube beyond the ſtomach. They are divided into the ſmall and the large. The ſmall inteſtines are ſubdivided into the duodenum, the jejunum, and the ileum. The large into the cœcum, the colon, and the rectum. All the inteſtines, except ſome part of the duodenum, are ſurrounded and ſupported by the meſentery. In man, the length of the inteſtines is about ſix times that of the body, but in graminivorous quadrupeds their length, in proportion to that of the body, is much greater.

The ſmall inteſtines fill the middle and fore-parts of the abdomen, while the large fill the upper and under parts, as well as the ſides of that cavity.

The ſmall inteſtines, in general, are of a cylindrical form. They are compoſed of four coats, the ſtructure of which is ſimilar, and which bear the ſame names as thoſe of the ſtomach. The muſcular coat, however,

 differs

differs from that of the ſtomach in one reſpect, that the longitudinal fibres are here leſs numerous, and the circular fibres much more ſo. The ſame fibre, however, does not wholly ſurround the inteſtine, as the circle is made of ſeveral imperfect arches. The cellular coat is exactly the ſame as that of the ſtomach. It affords ſtrength to the inteſtines, and conducts nerves and blood-veſſels to and from the villous coat. The villous coat of the ſmall inteſtines is exceedingly extenſive, and forms, together with the cellular ſubſtance, which connects it to the cellular coat, a vaſt number of red ſemilunar folds or wrinkles, which ſerve to increaſe remarkably the internal ſurface of the inteſtines, and of courſe to expoſe the chyle more fully to the mouths of the lacteals.

The ſmall inteſtines aſſiſt in the preparation of the chyle, and propel their contents towards the great inteſtines.

With reſpect to the ſmall inteſtines in particular, ſeveral circumſtances are to be noticed. The duodenum, ſo named from its being about twelve inches in length, differs from the others in not being entirely ſurrounded by the peritoneal coat; its muſcular coat, however, is ſtronger than that of the other ſmall inteſtines, and its colour is more florid. The duodenum, beginning from the ſtomach, firſt runs towards the right ſide downwards, and rather backwards; then it bends towards the right kidney, to which it is ſlightly connected, and thence paſſes before the renal artery and vein, aſcending gradually from right to left, till it gets before the aorta and laſt vertebra of the back. It continues its courſe obliquely forwards by a gentle turn, and then terminates in the jejunum. Through this whole courſe the duodenum is firmly bound down and concealed by the folds of the peritoneum. The duodenum

num is more lax, and of larger diameter than the other ſmall inteſtines, and by its various riſings and fallings is calculated to retain the food for ſome time before it paſſes into the jejunum. About ſix inches from the pylorus, the common bile duct and the duct from the pancreas pour their contents together into the duodenum.

Of the remaining part of the ſmall inteſtines, two fifths are called the jejunum, and the remaining three fifths the ileum, as no other characteriſtic mark of diſtinction can be pointed out. The upper part of the ſmall inteſtines is indeed uniformly more red, rather wider, and its ſtructure more robuſt than the lower part, but the gradation is regular. Nothing particular is to be obſerved at any part, which can furniſh a juſt foundation for a change of name, and Haller accordingly comprehended the jejunum and ileum under the term of inteſtinum tenue, or ſmall inteſtine. The jejunum is placed more about the umbilical region, the ileum more in the hypogaſtric. The ſmall inteſtines at length terminate in the large, in the hollow of the right iliac bone, below the kidney. At this place there is a valve, which exhibits the appearance of a ſlit or chink. This valve permits a free paſſage from the ſmall inteſtines to the large, but prevents any thing from paſſing readily from the large to the ſmall.

The cœcum, which forms the beginning of the great inteſtines, may be conſidered as a production of the colon expanded into a bag. It is about four fingers in length and as many in breadth. It is ſituated in the right iliac region, and reſts on the broad part of the os ileum. At its lower part it has a long ſmall proceſs, called the vermiform, from its reſemblance to an earth worm. This proceſs is plentifully furniſhed with mucus, which it pours into the cœcum. In apes this

proceſs is wanting, but its place is ſupplied by a gland, which affords a ſlippery fluid. In ſome birds we meet with two vermiform proceſſes, and in ſome kinds of fiſh they are very numerous. Under the name of colon is comprehended almoſt the whole of the great inteſtines. The colon begins in the right iliac region, and is attached to the kidney, thence it riſes as high as the ſtomach and the liver. It now runs tranſverſely before the ſtomach to the left ſide, is connected to the ſpleen and kidney, deſcends into the left iliac region, and being there bent in the form of the letter *S*, it terminates in the rectum. The ſtructure of the colon is ſimilar to that of the ſmall inteſtines. It is more robuſt, however, and the longitudinal muſcular fibres, which are mixed with ligamentous ſubſtance, are united into three faſciculi, giving it in ſome meaſure a triangular form. Theſe faſciculi are continued from the vermiform proceſs of the cæcum to the end of the colon, where they gradually diſappear.

Along the whole courſe of the colon are a number of cells formed by circular contractions of the inteſtine, which ſerve to retard the progreſs of its contents.

Along the whole courſe of the large inteſtines we alſo obſerve ſmall projections of a fat ſubſtance, contained in elongations of their common coat. They ſeem in their nature very analogous to the omentum, and are conſidered by Winſlow as a kind of ſmall omenta; they are accordingly named appendices epiploicæ.

The rectum, which is a continuation of the colon, begins at the loweſt vertebra of the loins. It is bent like the internal ſurface of the os ſacrum and os coccygis, to which it is cloſely applied, and terminates at the anus. The blood-veſſels of the inteſtines wil be mentioned in treating of the general diſtribution of the arteries and veins.

CHAP. XIX.

THE LIVER, SPLEEN, AND PANCREAS.

Nature and Situation of the Liver.—The Gall Bladder.—Bile Ducts.—Cause of Jaundice.—The Spleen.—The Pancreas.—Its Uses.

THE liver is an organ of a deep red colour, and is by far the largest gland in the body. It is situated immediately beneath the diaphragm. In man, the liver is divided into two portions or lobes, the larger of which is placed in the right hypochondrium, and the smaller extends across the epigastric region, towards the left. The liver is divided on the upper and anterior side into its lobes by a broad ligament, on the lower and posterior, by a deep fissure.

The upper surface of the liver is convex and smooth, corresponding to the concavity of the diaphragm. The lower surface is concave and uneven. The anterior and inferior margin of the liver is acute, the posterior and superior obtuse. At the back part of the liver, near the great fissure, there is a triangular eminence, called the small lobe of the liver, or lobulus Spigelii. The ligaments of the liver, by which it is supported, are four. Of these, one supports either lobe, and the broad ligament supports the middle. These ligaments are productions of the peritoneum, and are very different from what are called by the same name in other parts of the body. They pass from the diaphragm to the liver. Besides these, there is the round ligament, which is formed by the concretion of a considerable blood-vessel of the fœtus, and passes from the liver to the navel. Besides being supported by these ligaments,

the great lobe of the liver is likewiſe connected by immediate adheſion, without the intervention of the peritoneum, to the tendinous part of the diaphragm. Round this adheſion we may obſerve the peritoneum folded back, to form the external covering of the liver.

The blood-veſſels of the liver, which will be hereafter particularly conſidered, all enter on the concave ſide of this organ, where it is divided into its two lobes. The uſes of the liver are to ſecrete and prepare the bile.

The gall-bladder is a membranous receptacle, ſufficiently large to contain two or three ounces of bile. It is connected to the inferior part of the right lobe of the liver in ſuch a manner, that its fundus or bottom is placed forwards, and is in contact with the colon, and its neck is placed backwards. In ſhape the gall-bladder much reſembles a pear. It conſiſts of four coats, which are very ſimilar to thoſe of the inteſtines, and are called by the ſame names. The gall-bladder, as well as the liver, and the other viſcera of the abdomen are covered by the peritoneum.

The ducts, which ſerve to convey the bile formed in the liver to the duodenum, deſerve particular attention. The duct which comes from the liver, and is called the hepatic duct, is conſtituted of a number of ſmaller ducts, which riſe through the whole ſubſtance of the liver. This duct is joined to another coming from the gall bladder, and theſe ducts together conſtitute the common bile duct. The common duct deſcends towards the pancreas, and paſſing behind the duodenum, pierces its external coat. After having run between the coats of this inteſtine for ſome diſtance, it is at length, between its ſecond and third coat, united with the duct from the pancreas, and the fluids from the liver and pancreas

pancreas being thus mixed, are poured together into the cavity of the duodenum.

The gall-bladder in man receives all its contents by means of the communication between the cyſtic and hepatic ducts. In ſome animals, however, the gall-bladder receives its bile by peculiar ducts immediately from the liver, and in theſe animals the cyſtic and hepatic ducts do not unite. From the ſtructure and connection of theſe ducts in man it is evident, that all the bile which paſſes into the duodenum muſt paſs through the hepatic and common bile ducts, and that which goes to the gall-bladder paſſes through the cyſtic duct. The ducts are furniſhed with a muſcular coat. The uſe of the gall-bladder ſeems to be to retain the bile till its more watery parts being removed, the remainder may become thicker, more pungent, and more acrid. It is ſo placed that it may be preſſed upon by the diſtended ſtomach, and its contents therefore diſcharged when they are moſt required to aſſiſt in the proceſs of digeſtion. The gall-bladder is alſo emptied by the compreſſion and agitation of the viſcera, which happen in vomiting. The bile in the gall-bladder ſometimes concretes into hard maſſes called gall-ſtones. As long as theſe remain in the gall-bladder they occaſion little or no inconvenience, but when they are propelled into the ducts they diſtend and irritate them ſo as, when of a large ſize, to be productive of very violent pain. When theſe concretions are ſtopped in the common gall duct, they prevent the paſſage of bile into the inteſtines. The bile, not eſcaping in the uſual manner, is accumulated in the liver, and being taken up by the abſorbents is carried into the circulating ſyſtem, and produces jaundice.

The ſpleen is a ſpongy viſcus, of a colour between deep red and blue. Its figure is ſo irregular as to admit

admit of no deſcription; it is ſomewhat oblong, however, but is convex on the ſide which is applied to the ribs, and concave on that which is turned inwards towards the other viſcera of the abdomen, and where it receives its blood-veſſels. It is placed on the left ſide, in the left hypochondrium, and is oppoſite to the two laſt of the falſe ribs.

The ſpleen is connected to the ſtomach by blood-veſſels and a ligament, to the omentum, to the left kidney, to the poſterior part of the diaphragm by the peritoneum, to the pancreas by veſſels, and to the colon by a ligament. The ſpleen has only one coat, which can be diſtinctly perceived, and which is derived from the peritoneum. The ſpleen is extremely vaſcular, and when macerated ſeems wholly conſtituted of numerous blood-veſſels. It has no excretory duct, and it is remarkable, that though an organ of ſuch conſiderable ſize, its uſe is entirely unknown.

The pancreas is a glandular organ, of a pale red colour, and is called in certain animals the ſweetbread. The pancreas is ſituated in the epigaſtric region, behind the ſtomach, in the triangular ſpace ſurrounded by the windings of the duodenum. In form it reſembles the tongue of a dog, the narrow termination of which is placed towards the ſpleen, and is connected to that organ by blood-veſſels. The pancreas in the human ſubject is eight or nine inches in length but very narrow, and its ſituation in the body is very nearly tranſverſe. The liquor prepared by this gland is remarkably ſimilar to that prepared by the glands which furniſh ſaliva to the mouth; ſo that the pancreas may be conſidered as the largeſt ſalivary gland in the body. Like the ſalivary glands, the pancreas is a conglomerate gland, or conſiſts of a number of ſmall glandular

glandular maſſes united by cellular ſubſtance. Near the pancreas is obſerved a ſmaller gland of the ſame kind. This is called the little pancreas, and pours its contents into the pancreatic duct. We have already ſeen, that where the pancreatic duct pours its contents into the duodenum, it is united with the common bile duct.

Chap. XX.

THE ORGANS PLACED NEAR, BUT WITHOUT THE CAVITY OF THE ABDOMEN.

The Glandulæ Suprarenales.—The Kidneys.—The Bladder.

THE glandulæ ſuprarenales are two triangular bodies, the fabric of which is analous to that of glands. In the fœtus they are larger than the kidneys themſelves, over which they are placed; but in adults they are much ſmaller. They are hollow, and are filled with a reddiſh matter. The right ſuprarenal gland is fixed to the liver, the left to the ſpleen and pancreas, both to the diaphragm, and each of them to the kidney, above which it is placed. They are furniſhed with no excretory duct, and their uſe is unknown.

The kidneys are two organs of a pale red colour, and a firm conſiſtence, in form reſembling the beans which bear the ſame name. They are placed without the cavity of the abdomen, on each ſide of the ſpine, and extend acroſs the two loweſt falſe ribs as far as the bottom of the ſecond lumbar vertebra; they reſt on the great pſoas muſcle, the ſquare muſcle of the loins, and the tranſverſe of the abdomen, in ſuch a manner that the right kidney is placed below the liver and the colon, ſomewhat lower and further back, the left under the ſpleen, the ſtomach, the pancreas, and the colon, ſomewhat higher and more forwards. The length of the kidneys is about ſix inches, their breadth about four. Of the two margins of the kidneys, that which is placed outwards

is

is convex, that placed inwards concave. The kidneys are variouſly connected to the viſcera, which are next them. The right kidney is connected to the colon, which, as ſhould have been before remarked, is here partly without the cavity of the abdomen.

The kidney is made up of three different ſubſtances; firſt, an external part of a pale colour, which chiefly conſiſts of numerous convolutions of blood-veſſels, and is called the cortical part. The other two ſubſtances, that is the medullary or ſtriated, and the papillary, are really but one and the ſame maſs, of a redder colour. The radiated ſtriæ are continued into the papillary portion, where they terminate in about eleven or twelve papillæ, correſponding with the number of glandular portions, of which the kidney was originally compoſed. At the point of each papilla we ſee with the naked eye, in a ſlight depreſſion, ſeveral ſmall holes, through which the urine may be perceived to flow when the kidney is compreſſed. Each papilla lies in a kind of membranous calix or ſheath, which opens into a common cavity, called the pelvis. The pelvis is alſo membranous, being a continuation of the calix. In man the cavity of the pelvis is not uniform, but diſtinguiſhed into three portions, each of which contains a certain number of calices, together with the papillæ which they ſurround. The kidneys are ſurrounded with a ſtrong firm membrane, which is very cloſely applied about them. This, however, does not proceed from the peritoneum, but is connected to the poſterior part of that membrane by means of a large quantity of cellular ſubſtance, which is always plentifully filled with fat.

The urine, which is ſecreted in the kidney, drops from the papillæ into the pelvis. All the ſub-diviſions

fions of this bag ultimately terminate in a membranous canal, called the ureter, which, defcending between the peritoneum and the great pfoas mufcle, reaches the urinary bladder, to which it conveys the urine. The ureters of both kidneys enter the bladder at the pofterior part, near the neck, which is the moft fixed point. They run fome diftance between the coats of the bladder, before they open into its cavity, and this ftructure has the effect of a valve, in preventing the fluid when the bladder is very full, from returning towards the kidney.

The ureters are about a fpan long, and their canal is much wider in fome parts than in others. They are in general about the fize of a writing pen, and are fomewhat curved in their courfe from the kidney to the bladder, fo as to refemble the letter *ſ*. They are furnifhed with feveral coats, one of which is mufcular. They are very fenfible, as is proved by the acute pain which perfons who are fubject to the gravel experience while the ftones are paffing through them.

The urinary bladder is a membranous fack of confiderable fize. It is placed at the anterior part of the pelvis; when it is empty, it finks below the upper part of the offa pubis, but when filled, rifes confiderably above them. It is larger in women than in men. The upper part of the bladder is called its fundus, which is much wider than where it terminates in its neck. The anterior part of the bladder, which is placed next the offa pubis, is more flat, that turned backwards more convex. Its general form is a round oblong.

The bladder in men is connected behind to the rectum, and before it is always attached by cellular fubftance to the offa pubis. It is alfo connected to the navel

navel by ligaments, which are the remains of two arteries of the fœtus, and as its fundus projects into the cavity of the abdomen, the bladder is alſo connected to the peritoneum, which covers part of its fundus.

The coats of the bladder are, firſt, a coat of cellular ſubſtance, by which it is connected to the neighbouring parts; 2dly, a muſcular coat, the fibres of which, beginning from the neck, aſcend on both ſides, towards the fundus. At the neck the fibres croſs each other, and in this manner form a ſphincter, by which animals are enabled to retain the urine; and yet a continuation of the ſame fibres towards the fundus aſſiſts in expelling it. In this part, as well as in the tongue and mouth, we have an inſtance of the different parts of the ſame muſcular fibres counteracting each other.

The third coat of the bladder is like the nervous coat of the inteſtines, and bears the ſame name. The inner coat has many foldings, and is plentifully ſupplied with mucus. The fundus of the bladder alſo derives a coat from the peritoneum. The uſes of the bladder are to receive the urine, to retain it for a time, and to expel it through the urethra from the body.

Had the peritoneum been ſpread over the bladder in its whole extent, the weight of the viſcera in our erect poſture would have ſo borne upon it, that a conſiderable quantity of water could not have been collected there. The peritoneum, however, by paſſing from the ſides of the abdomen over the ſuperior part of the bladder, forms a ſupport for the incumbent viſcera, and preſerves a certain ſpace below, where they cannot preſs. In the quadruped, where, from the horizontal poſition of the body, the abdominal viſcera do not

not preſs on the bladder, that organ is entirely inveſted with the peritoneum.

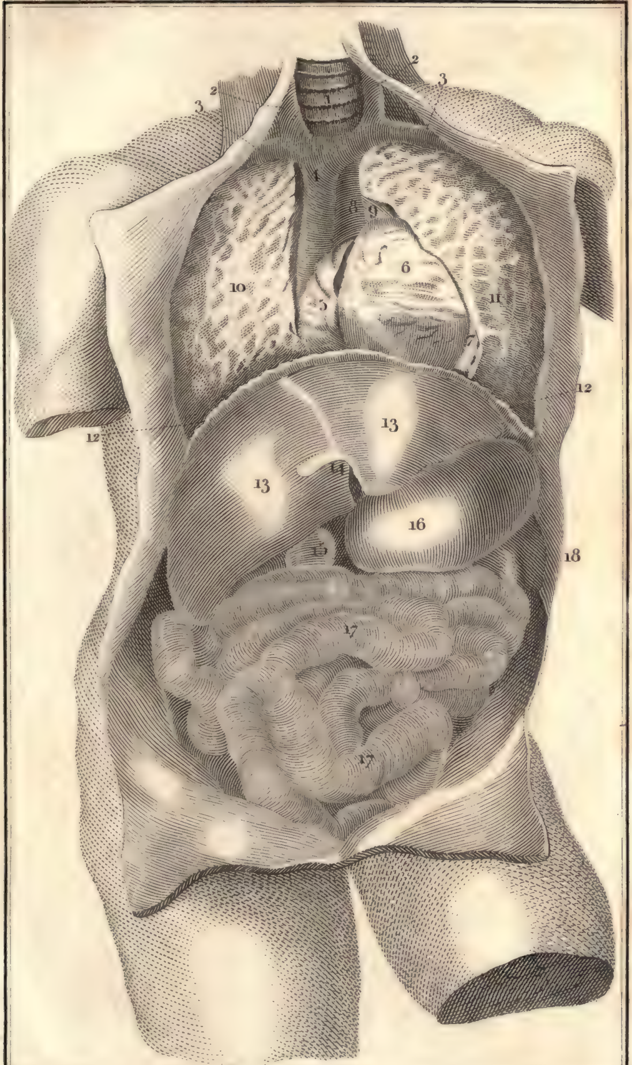
The figure in plate X. repreſents,

1. The trachea.
2. The internal jugular vein.
3. The ſubclavian vein.
4. The vena cava deſcendens.
5. The right auricle of the heart.
6. The right ventricle, the pericardium being removed.
7. Part of the left ventricle.
8. The aorta aſcendens.
9. The arteria pulmonalis.
10. The right lobe of the lungs, part of which is cut off to ſhew the great blood veſſels.
11. The left lobe of the lungs.
12. The diaphragm.
13. The liver.
14. The ligamentum rotundum.
15. The bottom of the gall-bladder projecting beyond the anterior edge of the great lobe of the liver.
16. The ſtomach, preſſed by the liver towards the left ſide.
17. The ſmall inteſtines.
18. The ſpleen.

The figure in Plate XI. repreſents.

1. The under ſide of the liver.
2. The ligamentum rotundum.
3. The gall-bladder.
4. The pancreas.
5. The ſpleen.

6. The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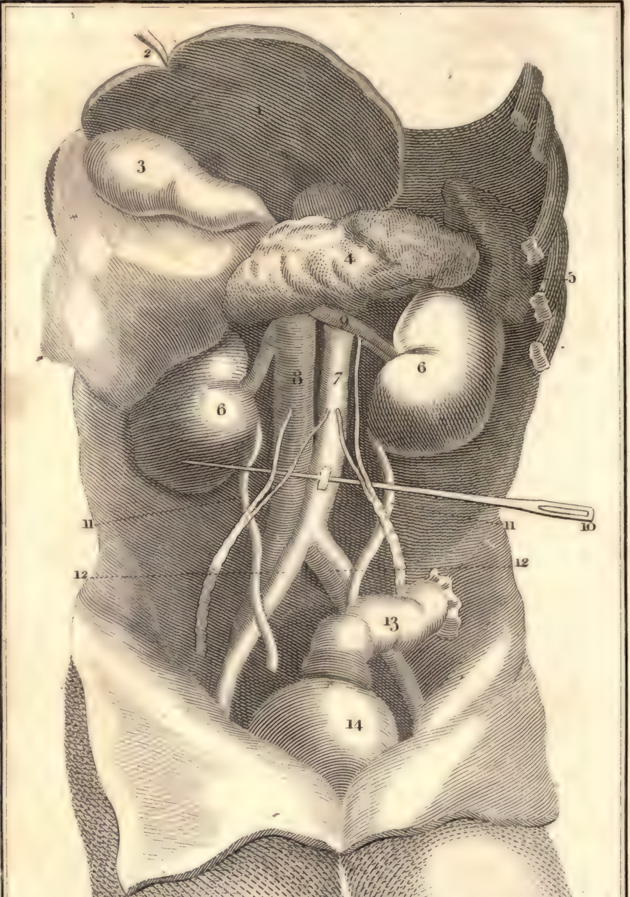
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6. The kidneys:
7. The aorta deſcendens.
8. The vena cava aſcendens.
9. The emulgent vein.
10. A probe under the ſpermatic veſſels and the arteria meſenterica inferior, and over the ureters.
11. The ureters.
12. The iliac veſſels.
13. The inteſtinum rectum.
14. The urinary bladder.

Chap. XXI.

THE CAVITIES OF THE MOUTH AND FAUCES, &c.

The Palate.—The Pharynx.—The Oesophagus.—The Larynx.—The Glottis.—The Epiglottis.—The Windpipe.

IT is unneceſſary to enumerate the parts which externally limit the cavity of the mouth, as the lips, cheeks, &c. ſince they are obvious to common obſervation. Within the mouth are the bony proceſſes which include the teeth, and which are covered by the gums. The upper and arched part of the mouth is called the palate. The palate is divided into the hard and the ſoft. The hard palate is bounded by the teeth, and is formed by the two oſſa maxillaria and oſſa palati covered with the perioſteum and the common coat of the inſide of the mouth, which produces, particularly in ſome animals, a number of hard ridges. The ſoft palate or velum pendulum palatinum is a ſeptum, which ariſes from the external margin of the palate bones, and laterally from a proceſs of the ſphenoid bones. It is a moveable ſoft ſubſtance, hanging between the cavity of the mouth and the poſterior termination of the noſtrils.

The ſoft palate is compoſed of the common membrane of the mouth and noſe, and includes a number of mucous glands, and ſome muſcular ſubſtance. It forms two arches on each ſide, deſcending from the hard palate. The two anterior of theſe arches are ſmaller and thinner, and are inſerted laterally into the tongue; the two poſterior are large, and are connected behind to the pharynx. In the middle and upper part, where all

all the half arches unite, they are lengthened into a ſmall pointed body, which is eaſily ſeen at the back part of the mouth, and is called the columella or uvula. On each ſide, in the bottom of the ſpace which is left between the anterior and poſterior arches, is placed an oblong glandular body, which opens into the throat by eleven or twelve excretory ducts, and is called the amygdala or tonſil. We have the power of ſtopping the paſſage of air from the noſe, by drawing up the ſoft palate, ſo as to cover its poſterior openings. The whole cavity of the mouth is moiſtened by mucus, and the liquor from the ſalivary glands.

The glands which furniſh the mouth with ſpittle or ſaliva are the two parotids, which are ſeated immediately below the ears; the maxillary, which are ſeated at the inſide of the angles of the lower jaw; the ſublingual, which are placed between the bone of the lower jaw and the tongue; and laſtly, a number of ſmall glands, placed in bunches about the opening of the ducts, which come from the parotid glands. The ſtructure of the ſalivary glands is like that of the pancreas.

I ſhall defer the deſcription of the tongue till I come to treat of the ſenſe of taſting. The noſe, the ear, and the eye, will be deſcribed when I treat of the ſenſes to which they are ſubſervient.

The cavity behind the palatum molle or ſoft palate is called the pharynx. At the back part it is bounded by the vertebræ of the neck, above by the baſe of the cranium, before and laterally by the ſoft palate and much cellular ſubſtance, and every way by the muſcles which ſurround the neck. The noſtrils terminate at their poſterior opening in the cavity of the pharynx, as do laterally the two euſtachian tubes from the internal part of the ear.

The pharynx is a muſcular bag ſhaped like a funnel,

beginning from the base of the cranium and terminating below in the œsophagus or gullet. Its substance is merely muscular, covered with the same tender and glandular membrane which lines the mouth, fauces, and œsophagus. The use of the pharynx is to receive the aliment and impel it into the œsophagus.

The œsophagus or gullet is a membranous tube, beginning from the narrow termination of the pharynx. It is placed between the vertebræ of the neck and the windpipe, and descending lower is embraced by the pleura, and lies in a triangular space behind the mediastinum. Having arrived at the bottom of the thorax it passes through the left perforation of the diaphragm, and terminates in the cardia, or left orifice of the stomach.

The œsophagus has four coats. First, a covering from the pleura; secondly, a muscular coat of considerable power; thirdly, a cellular coat; and lastly, a tender internal coat, like that of the fauces, and which is copiously supplied with mucus. The œsophagus conveys the food to the stomach.

The larynx is a hollow tube composed of cartilages, muscles, and ligaments, situated behind and below the tongue, at the anterior part of the neck. The larynx is connected above to the os hyoides, behind to the root of the tongue and the pharynx.

The cartilages of the larynx are the cricoid or annular, which is narrow before and broad behind, and is there divided into two excavations, which receive the arytenoid or pyramidal cartilages. The cricoid cartilage forms the basis of the whole larynx. It is connected below to the windpipe, and above to the pyramidal and thyroid cartilages.

The thyroid cartilage rests perpendicularly on the cricoid, and constitutes the upper, anterior, and largest

part of the larynx. It consists of two almost quadrangular plates of cartilage, which unite before at an obtuse angle, but behind are separate. This cartilage is harder and more prominent in men than in women, and has therefore been called the pomum Adami. At its posterior part the thyroid cartilage has processes above and below. The upper are united by means of ligaments with the processes of the os hyoides. The lower, which are shorter, are connected to the cricoid cartilage. The two arytenoid cartilages are the smallest, which contribute to form the larynx. They are equal in size, and when joined together resemble the spout of an ewer. They are placed perpendicularly in two excavations of the cricoid cartilage at its posterior part. The glottis is formed of two ligaments, in the following manner:

Anteriorly the base of each arytenoid cartilage is fixed to one end of a ligamentary cord, which, by its other end, is inserted about the middle of the concave side of the anterior portion of the thyroid. At the latter insertion the two ligaments touch each other; but a small space is left between them, where they are connected with the arytenoid cartilages. This chink is what is called the rima glottidis, which is capable of contraction and dilatation.

Under these ligaments are two smaller, which also arise from the arytenoid cartilages, and, running forwards, are attached to the middle part of the thyroid cartilage. Between these superior and inferior ligaments there is on each side a small bag or cavity, called the ventriculus Galeni.

Over the opening of the larynx, the rima glottidis, is placed a cartilaginous substance, called the epiglottis; it is situated above the anterior or convex portion of the cartilago thyroids, and its lower extremity is con-

nected by a ſhort, broad, and very ſtrong ligament, to the middle notch in the upper edge of that cartilage. The epiglottis is ſomewhat concave behind and convex before. Its ſhape reſembles that of the tongue, and its termination or apex is always free, ſo as by its own elaſticity to be naturally elevated. In deglutition, however, when the tongue is drawn backwards, the epiglottis is exactly applied over the rima glottidis, ſo as to prevent the food from paſſing into the larynx, or, as is commonly ſaid, going the wrong way.

The pharynx is every where connected by muſcular fibres to the larynx, and the larynx is in a manner ſuſpended in its cavity. At the anterior part of the larynx is placed a gland of conſiderable ſize, called the thyroid gland. It is not diſcovered to have any excretory duct, and its uſe is unknown.

The muſcles which regulate the motions of the glottis, which is the principal organ of the voice, are the following four pairs, and one ſingle muſcle:

The crico-arytenoideus poſticus ariſes from the cricoid cartilage, and is inſerted into the poſterior part of the baſe of the arytenoid cartilage. By its contraction it opens the rima glottidis a little, and by pulling back the arytenoid cartilage, renders the ligament tenſe.

The crico-arytenoideus lateralis proceeds from the cricoid cartilage laterally, where it is covered by part of the thyroid, and is inſerted into the baſe of the arytenoid cartilage. Its effect is to open the rima glottidis, by ſeparating the arytenoid cartilages, and conſequently the ligaments which are fixed to them.

The thyreo-arytenoideus ariſes from the thyroid cartilage, runs backwards along the ſide of the glottis, and is inſerted into the arytenoid cartilages. Its effect is to bring the thyroid and arytenoid cartilages nearer to each

each other, and consequently to relax the ligaments which are placed between them.

The arytenoideus obliquus arises from the base of one arytenoid cartilage, and crossing its fellow, is inserted into the tip of the other. When both act, they pull the arytenoid cartilages towards each other, and therefore contract the rima glottidis.

The single muscle which was mentioned is the arytenoideus transversus. It arises from the side of one arytenoid cartilage and passes to the other. It shuts the rima glottidis by bringing the arytenoid cartilages with the ligaments nearer each other.

Besides these, there are a few separate muscular fibres, which from their connections are called

The thyreo-epiglottideus, which arises from the thyroid cartilage, and is inserted into the epiglottis laterally. It draws the epiglottis obliquely downwards.

The aryteno-epiglottideus, which arises from the side and upper part of the arytenoid cartilage, and is inserted with the former into the epiglottis; it pulls down the epiglottis, and counteracts the effect of its elasticity.

The aspera arteria, or windpipe, is a tube formed of annular cartilages, membranes, and muscular fibres. It begins from the annular cartilage of the larynx, descends rather towards the right side of the spine into the cavity of the thorax, and is divided into two great branches, which being afterwards subdivided, obtain the name of bronchia, and are distributed through the substance of the lungs. The aspera arteria is furnished with two membranes, the outer of which is formed of cellular substance, and the inner is very soft and tender; between these membranes are placed the cartilaginous rings. These rings are connected to each other by ligamentous fibres above and below. They do not form

complete circles, but are imperfect behind, where the circle is completed by a ſoft but ſtrong glandular and muſcular membrane. The cartilaginous rings are thin and elaſtic, but thicker and broader before than at their ſides. They are largeſt at the upper part of the windpipe, and are found to be ſmaller as we advance lower. Of the muſcular fibres ſituated between the cartilaginous rings, ſome are circular, which render the windpipe narrower, and others longitudinal, which render it ſhorter.

The windpipe in the upper part of the cavity of the thorax is divided as was before ſtated into two great branches, the larger and ſhorter of which goes to the right lobe of the lungs, the ſmaller and longer to the left.

The ſtructure of the branches of the windpipe, till they enter the ſubſtance of the lungs, is the ſame as that of the windpipe; after they enter the lungs, however, the cartilaginous rings ſoon diſappear, and nothing but a thin elaſtic coat remains. The ultimate diviſions of the windpipe terminate in the air-veſſels of the lungs.

CHAP. XXII.

THE PLEURA, THE LUNGS, AND THE THYMUS.

Deſcription of the Thorax.—The Pleura.—The Breaſts.—Breaſts of Infants contain Milk.—The Mediaſtinum.—The Lungs.—The Thymus.

THE thorax is that part of the body which lies between the neck and the diaphragm. It is ſurrounded by the ſpine, the ribs, the ſternum, and the diaphragm, and alſo, internally, by a thin membrane like the peritoneum, which forms two ſeparate cavities, and is called the pleura. On the external part of the thorax are placed the mammæ or breaſts; within is the heart, with its large veſſels, and the lungs.

The mammæ, or breaſts, in men, and children of both ſexes, are no more than cutaneous tubercles, with a browniſh circle in the middle, called the areola. In women they are two convex firm bodies, of a glandular nature. In the middle of each breaſt is a prominent ſpongy ſubſtance, called the papilla, perforated by a number of ducts for the diſcharge of the milk, around which is placed the areola. The internal part of the breaſt chiefly conſiſts of a large quantity of fat; but there is alſo a large glandular ſubſtance, compoſed of many ſmaller glands, connected together by cellular membrane; this is the organ which ſecretes the milk, and to which the term mamma is more ſtrictly applicable. It is remarkable, that a ſmall quantity of milk may in general be preſſed from the breaſts of new-born infants, both male and female.

The pleura, as has been intimated, is a tranſparent and denſe membrane, continued through the left perforation

foration of the diaphragm from the peritoneum. It covers the internal ſurface of the bones of the thorax and the upper part of the diaphragm, and involves the viſcera of the thorax in the ſame manner as below it involved thoſe of the abdomen. The internal ſurface of the pleura is conſtantly moiſtened, and rendered ſlippery by a ſerous exudation.

The mediaſtinum is formed by two laminæ of the pleura including cellular ſubſtance. Theſe are cloſely connected near the ſternum and vertebræ; but in the middle and towards the lower part they are ſeparated by the pericardium and heart. Before the heart, from the pericardium to the ſternum, the two laminæ adhere very cloſely; higher up they are divided to receive the thymus. The mediaſtinum divides the thorax perpendicularly into two ſeparate cavities or ſacks, which contain the lungs. The mediaſtinum is attached in ſuch a manner to the anterior part of the bones of the thorax, as to render the right ſack of the pleura larger than the left. Behind, the mediaſtinum is attached to the dorſal vertebræ, before to the ſternum, below to the diaphragm and pericardium, and above to the large blood-veſſels.

Behind, towards the vertebræ of the back, is left a triangular ſpace, in which is placed the windpipe, the œſophagus, the thoracic duct, and ſeveral large blood-veſſels; before, the gland called the thymus occupies a ſimilar ſpace. The uſes of the pleura are to furniſh an internal covering to the bones of the thorax and the diaphragm, and an external covering to the thoracic viſcera.

The union of the two ſacks of the pleura, forming the mediaſtinum, is of uſe, by ſupporting the lungs, and by preventing their preſſure on each other when the body is turned to either ſide. By the two ſides of the

the thorax being thus ſeparated, one may be wounded without impeding the functions of the other.

The lungs fill the two ſaoks of the pleura, one of which is placed on each ſide of the mediaſtinum. With reſpect to the form of the lungs, their baſes are broad, and their ſummits form an obtuſe cone. Their anterior ſurfaces, and thoſe applied to the mediaſtinum, are flat, that next the ribs is ſomewhat convex, and that behind round. The lower part of the left lung is excavated to make room for the heart. The colour of the lungs is in infants reddiſh, in adults greyiſh, and in old age they verge towards dark blue or black; their ſurface is uſually mottled.

The lungs are connected above to the neck by means of the windpipe, and below by blood-veſſels to the heart. They have no other covering but the pleura, connected to them by the intervention of thin cellular ſubſtance, which in this part is always free from fat.

With reſpect to the ſtructure of the lungs, the right, which is larger, conſiſts of three lobes, the left only of two; all of theſe are ſubdivided into a number of ſmaller lobes called lobules. Theſe diviſions are connected to each other by the intervention of cellular ſubſtance. The ſubſtance of the lungs is ultimately made up of minute veſicles, called the air-veſſels of the lungs, which are the terminations of the windpipe.

Theſe veſicles have extremely thin coats, and on theſe coats are diſtributed the minute ramifications of the blood-veſſels which go to the lungs. It has been computed, from the extreme minuteneſs of the air-veſſels, that the internal ſurface of the lungs is not leſs extenſive than the floor of a moderate ſized ſitting room. Theſe air-veſſels communicate with each other through

through the whole ſubſtance of each lung, ſo that by inflating one lobule the air paſſes into the reſt. The uſes of the lungs are of the moſt important nature, and will be conſidered in a ſeparate chapter on the ſubject of reſpiration.

The thymus, the ſituation of which has been juſt mentioned, is ſoft, and of a ſpongy texture. It is very large in the fœtus, and is filled with a white thin liquor; in adults it is hard, ſmall, and gradually decays. It is not diſcovered to have any excretory duct, and its uſe is unknown.

Chap. XXIII.

THE HEART.

The Pericardium.—The Heart.—The Ventricles and Auricles.—Their Uſes.—General View of the Blood-veſſels.

THE heart is a hollow muſcle, included in a membranous bag, called the pericardium.

This membrane incloſes not only the heart, but the great veſſels which ariſe from it. This covering of the heart conſiſts of three laminæ; the external of theſe is formed by a duplicature of the mediaſtinum. The middle lamina, which is the thickeſt and ſtrongeſt, is compoſed of very fine tendinous fibres, which at the lower part are connected and mixed with thoſe of the diaphragm. The internal lamina ſeems to be a continuation of the outer coat of the heart and great veſſels. Within the pericardium is found a quantity of tranſparent liquor, which facilitates the motions of the heart, by preventing friction.

The heart is placed in man almoſt tranſverſely, and reſts on the diaphragm at the anterior part of the thorax. The baſe or broad part of the heart is directed towards the right ſide, its point or apex towards the left, and this latter is ſo placed, as when the heart beats to ſtrike the ſixth rib. The upper ſurface of the heart is convex; the lower, which reſts on the diaphragm, is flat. The greater part of the heart lies in the left cavity of the thorax.

The ſubſtance of the heart is muſcular, and is compoſed of fibres, which, ariſing from the baſe, where it is tendinous, take a winding courſe towards its apex in various directions.

The

The principal part of the muſcular ſubſtance of the heart forms two cavities called the ventricles. The poſterior or left ventricle of theſe is much thicker, ſtronger, longer, and rounder than the other; the anterior or right ventricle is wider, ſhorter, and thinner *. The ſeptum, or that portion of muſcular ſubſtance which is placed between the ventricles, ſeems chiefly to belong to the former, and gives the latter an appearance of being merely an appendage.

At the baſe of the heart are two cavities, which are each of them divided by anatomiſts into two parts, the ſinus and the auricle; but as theſe together form one cavity, it will anſwer beſt the purpoſe of perſpicuity to ſpeak of them ſimply by the name of auricles. The auricles are compoſed of two membranes, with ſome muſcular fibres. Like the ventricles, they are ſeparated from each other by a ſeptum, and one of them obtains the appellation of the anterior or right auricle, the other that of the poſterior or left. Each of them communicates with the ventricle which is placed next it, and which bears the ſame name.

Between the auricles and ventricles of the heart are placed valves, as alſo at the mouths of the great arteries, which prevent the blood from paſſing in any other than the proper direction.

The valves, which are placed between each of the auricles and ventricles, are turned inwards towards the latter cavities. The valves, ſituated at the entrance of the anterior ventricle, have three remarkable points,

* The terms anterior and poſterior auricles and ventricles of the heart are uſed as deſcriptive of the ſituation of them in man. In quadrupeds, the anterior auricle aud ventricle, or thoſe which perform the ſame purpoſe, are placed towards the right ſide, and the poſterior towards the left.

and are therefore called valvulæ tricuſpides; thoſe of the poſterior ventricle terminate in two points, and from being compared to a mitre, are called valvulæ mitrales. In each of the great arteries, which proceed from the ventricles, the aorta and pulmonary artery, are ſeated three valves turned from the ventricles, and are called ſemilunares. All theſe valves are elongations of the internal membrane of the part to which they belong. They are cloſely connected on that ſide from which the current of blood proceeds, and their other extremity is looſe. When the blood, therefore, proceeds in its proper courſe, they are preſſed cloſe to the ſide of the veſſel, and occaſion no impediment; but when it is about to return in the contrary direction, they are raiſed from the ſide of the veſſel, and meeting in the middle of its cavity, ſhut up the channel. The internal ſurface of the ventricles is extremely uneven, from a number of fleſhy columns which riſe from its inſide, and ſome of which terminate by tendinous extremities in the valves of the heart, which they ſupport, and enable to perform their office more effectually.

Beſides the connection, however, between the auricles and ventricles of the heart, each auricle communicates with a large vein, and each ventricle with a large artery. The uſe of the auricle is to receive the blood from the vein, and to diſcharge it into the cavity of the ventricle. The ventricle receives the blood from the auricle, and drives it forcibly into the artery. By a repetition of thoſe actions is performed the circulation of the blood, which is the ſubject of another chapter, in which I ſhall take occaſion to mention ſome remarkable varieties in the hearts of different races of animals.

The

The vessels of the human body are either blood-vessels or lymphatics.

The blood-vessels are membranous tubes, which convey the blood to and from the various parts of the body. They are divided into arteries and veins. The arteries pulsate, and convey the blood from the heart; the veins return it towards the heart, and do not pulsate *. The large trunks, both of the arteries and veins, are near the heart; at a distance from it they are divided into numerous small branches in a manner very similar to that in which the trunk of a tree is lost in its branches and twigs.

The arteries are formed by the following tunics. The first is derived from the cavity, through which the artery passes; in the thorax, from the pleura; in the abdomen, from the peritoneum, &c. The second is a loose covering of cellular substance, which contains smaller vessels, for the nourishment of that on which they run, and which in the large arteries often contains a considerable quantity of fat. The third is muscular, and is composed of several small arches of muscular fibres, many of which go to the formation of a circle. Within this is a thin cellular coat, which adheres closely to the former; and lastly, there is a firm, smooth, and whitish coat, with which the circulating mass of fluids is in contact.

The structure of the veins is the same as that of the arteries, but more delicate. The muscular coat is in them so thin, or of so pale a colour, as not to admit of demonstration in man, but is plainly seen in a vessel called the vena portarum of the ox. That

* As a pulse is only to be perceived in the arteries, this circumstance will enable the most unskilful to distinguish the nature of any blood-vessel.

veins,

veins, however, have muſcular coats in all animals, is inferred from their contractile power.

The venous ſyſtem is far more capacious than the arterious.

Arteries are commonly ſaid to diminiſh in ſize, as they recede from the heart; but this is not the real ſtate of the caſe. As long as an artery continues undivided, its diameter remains the ſame; and when it does divide, the area of the veſſels formed by this diviſion is always greater than the area of the artery from which they are produced; ſo that the artery may in truth be ſaid to be increaſed. This rule holds equally with reſpect to the diviſion of the great trunks of arteries, and the ſub-diviſions of their branches. The trunks alſo of veins are always ſmaller than the ſum of the ſmaller veins from which they are formed.

The larger trunks of blood-veſſels are ſeparate tubes, but their branches form various communications with each other, and theſe communications increaſe as the veſſels become more minute, ſo as at length to form a web of veſſels in the parts on which they are diſtributed. The advantages of this ſtructure are very obvious, as by a communication of veſſels each part may receive blood from many ſources, and no part therefore ſuffers by the diviſion of the blood-veſſel which more particularly belongs to it; its advantages are like thoſe of commerce among mankind, by which the effects of partial loſſes are guarded againſt by a mutual exchange of conveniencies.

The branches of arteries are in general ſent off at much more acute angles than thoſe of the veins, by which the paſſage of the blood through the arteries is the leſs impeded.

The arteries have in general a correſponding vein placed near them; but to this rule there are ſeveral

exceptions, which will be more particularly noticed in ſpeaking of the venous ſyſtem. The trunks of the veins, and almoſt all the arteries, are deeply ſeated; but the ſmaller veins are every where thickly diſtributed on the ſurface of the body, immediately below the ſkin. By this ſtructure a paſſage is provided for the blood on the ſurface of the body, where the internal veins are ſo compreſſed by the action of muſcles as not eaſily to tranſmit their contents. The external and internal veins communicate very freely.

Chap. XXIV.

GENERAL DISTRIBUTION OF THE ARTERIES.

The Aorta.—The coronary Artery.—The carotid and ſubclavian Arteries.—The intercoſtal Arteries.—Bronchial Arteries.—The Cœliac Artery.—Meſenteric Arteries.—Renal Arteries.—Lumbar Arteries.—Iliac Arteries.—Crural Artery.—Pulmonary Artery, &c.

FROM the poſterior, inferior, or left ventricle of the heart proceeds the principal artery of the body, called the aorta. Immediately on leaving the heart it ſends off two ſmall arteries, called the coronary, which are diſtributed on the heart itſelf. The aorta now riſes three or four inches above the heart, when it is turned backwards and towards the left ſide, forming an arch over the left diviſion of the windpipe. From the convex ſide of its arch, the aorta ſends off three large arteries, which go to the head and arms. The firſt of theſe is equal to the two other in ſize, and ſoon divides into two branches; of theſe one is the right carotid artery, which is diſtributed on the right ſide of the head; the other is the right ſubclavian, which proceeds to the right arm. The arteries which belong to the left ſide of the head and left arm ariſe ſeparately from the aorta, and are the two other branches which were mentioned as being ſent off from its arch.

Upon meaſuring the ſides of the veſſels, the ſurface of the united trunk of the right ſubclavian and carotid is leſs than that of the left ſubclavian and carotid, which ariſe ſeparately; if ſo, the reſiſtance to the blood muſt be leſs in that common trunk than in the left ſub-

 clavian

clavian and carotid. The resistance being smaller, the impetus and velocity of the blood must be less affected; and as the strength of the muscles is as the quantity of blood sent into them in a given time, those of the right arm will be stronger than those of the left. This therefore accounts in some measure for the preference which is generally given to the right arm, though it must be acknowledged that it is difficult, from this reasoning, to account for the preference which some children give to the left. The right subclavian and carotid sometimes arise separately like the left, but it has not been ascertained that this exception to the usual structure happens more frequently in left than in right handed persons. In quadrupeds we observe something of the same preference of the right limbs, and attended with the same distribution of the arteries. In birds, which must be nicely balanced, the arteries of both sides come off alike.

The two carotid arteries proceed upwards on each side of the windpipe, behind the sterno-cleidomastoideus muscle, and the platisma myoides, as high as the larynx, without a division. About this part the carotid artery is divided into two others, called external and internal carotid arteries. The external carotid supplies the parts about the larynx, the face, the external parts of the head and the dura mater. The other division of the carotid is distributed almost entirely on the brain, and is therefore called the internal carotid artery. It first proceeds to the lower orifice of the great canal of the pars petrosum of the temporal bone. After being contorted according to the course of this passage, it at length enters the cavity of the cranium, at the side of the sella turcica. As it leaves the bony canal, it sends off an artery, which supplies the contents of the orbit,

orbit, and which communicates with twigs of the external carotid about the face.

The internal carotid afterwards runs under the baſe of the brain at each ſide of the infundibulum, where it is at a ſmall diſtance from the carotid artery of the other ſide. At this part it commonly divides into two branches, one of which paſſes towards the anterior, the other towards the poſterior part of the brain, where it communicates with the vertebral artery of the ſame ſide. The arteries of the brain are incloſed in the folds of the pia mater, and are not diſtributed on the ſubſtance of the brain itſelf, till after having undergone a minute diviſion.

The ſubclavian arteries are ſo called, becauſe they paſs under or behind the clavicles. Each ſubclavian artery ſends off a conſiderable one to the internal parts of the head. They proceed from the upper and poſterior part of the ſubclavian, and obtain the denomination of the vertebral arteries, becauſe they paſs through openings in the tranſverſe proceſſes of the vertebræ of the neck. Having reached the great foramen of the os occipitis, they enter the cranium, and pierce the dura mater. The two vertebral arteries, after they have entered the cranium, gradually advance towards each other, and at length unite, forming the arteria baſilaris.

The ſubclavian artery alſo ſends off twigs to the mediaſtinum, thymus, trachea, and pericardium. It alſo ſends off two branches of a larger ſize, called the mammaria interna, and cervicalis, beſides the vertebralis, which has been already deſcribed.

The ſubclavian artery, where it leaves the thorax, immediately above the firſt rib, changes its name to that of the arteria axillaris, becauſe its paſſes under the axilla. In this courſe it gives off four principal

branches, the thoracica superior, mammaria externa, thoracica humeralis, and axillaris scapularis, which are distributed on the parts from which they derive their names. The arteria axillaris, where it passes behind the tendon of the pectoralis major, again changes its name to that of the arteria brachialis. Between the axilla and the middle of the arm, the artery is only covered by the common integuments; below this it passes under the biceps muscle, and runs obliquely forwards as it descends. In its course, it continues to send off branches to the adjoining parts. A little more than a finger's breadth below the bend of the arm, the arteria brachialis divides into two branches, called the cubitalis and radialis, the former of which lies next the ulna, the latter next the radius.

The aorta, having completed its arch, is directed downwards, being situated towards the left side of the spine. Below the fourth vertebra of the back, it obtains the name of the descending aorta, which, between this part and the diaphragm, sends off the following branches:

The inferior intercostal arteries are generally seven or eight on each side. They arise in pairs along the posterior part of the aorta, and run transversely towards each side on the bodies of the vertebræ. They afterwards pass in the bony ridge at the inferior edge of the ribs, almost as far as the sternum, being distributed in their course on the intercostal muscles.

The bronchial arteries are two or three in number, which sometimes arise from the aorta, sometimes are branches of the superior intercostal, or of the arteries of the œsophagus. They enter with the divisions of the bronchia into the substance of the lungs, on which they are distributed.

The arteries of the œsophagus are generally two or

or three in number. They ariſe from the anterior part of the aorta, and are diſtributed on the œſophagus.

One or more arteries are alſo ſent to the diaphragm, and diſtributed on its lower ſurface.

Below the diaphragm, the deſcending aorta ſends off

The cœliac artery, which ariſes from the anterior part of the aorta by a ſhort trunk, which divides into three principal branches; one runs upwards, and is called the coronary artery of the ſtomach, and is chiefly diſtributed on that organ; another runs towards the right, and having ſent off one or two branches to the ſtomach and duodenum, joins the vena portæ, enters the fiſſure of the liver, and is diſtributed through its ſubſtance; the third is directed to the left, under the ſtomach and pancreas, to the ſpleen. In its progreſs it diſtributes ſmall branches to the ſtomach, pancreas, and omentum.

At a ſhort diſtance below the cœliac, the ſuperior meſenteric artery proceeds from the anterior part of the aorta. Near its origin it ſends off a ſmall branch, which carries blood to the large extremity of the pancreas, and the neighbouring part of the duodenum. Being included between the laminæ of the meſentery, it forms a kind of arch, which deſcends obliquely from left to right, and from which about ſixteen or ſeventeen branches are ſent off, moſt of which are ſpent on the ſmall inteſtines. As theſe branches approach towards the inteſtines, and are more minutely divided, they inoſculate and communicate very freely with each other, ſo as at length to ſurround the inteſtines like net work. From the concave ſide of the arch proceed ſeveral branches, one of which is of great length, and makes a remarkable communication with the inferior meſenteric artery. From the numerous communications among the arteries of the inteſtines, we may obſerve how

carefully theſe parts are provided with a ſupply of blood.

The next arteries, which are ſent off from the aorta, are the two emulgent or renal. They ariſe one on each ſide, and proceed almoſt horizontally to the kidneys. As the aorta lies towards the left ſide of the ſpine, the right renal artery is longer than the left. The reverſe is the caſe with the veins, as the vena cava is placed on the right ſide of the ſpine.

Above the renal arteries ariſe two arteries, which go to the glandulæ ſuprarenales, and which alſo ſend branches into the adipoſe membrane which ſurrounds the kidneys.

Below the renal arteries ariſe the two ſpermatic arteries, which are very ſmall. They are placed behind the peritoneum, on the pſoas muſcles.

The lower meſenteric artery ariſes from the anterior part of the aorta, below the ſpermatic. It is ſoon divided into three or four branches, which gradually ſeparate from each other. The ſuperior of theſe branches forms the communication, which was mentioned as taking place between the two meſenteric arteries. The inferior meſenteric artery is diſtributed chiefly on the colon; it ſends, however, a conſiderable branch to the rectum, called the arteria hæmorroidalis interna.

The lumbar arteries proceed in five or ſix pairs from the poſterior part of the aorta, much in the ſame manner with the intercoſtals. The ſuperior ſometimes ſend blood to the diaphragm and intercoſtals, but they are principally ſpent on the pſoas muſcles, the quadrati lumborum, and the oblique and tranſverſe muſcles of the abdomen. One or more arteries are ſent off from the lower part of the aorta, or ſome of the neighbouring arteries, to the os ſacrum and large nerves of theſe parts.

Near the laſt lumbar vertebra, the aorta is divided into two equal trunks, called the common iliac arteries, one of which lies to the right the other to the left, and which recede from each other as they deſcend. About three fingers breadth from their origin, each iliac trunk is divided into two ſecondary arteries. One of theſe, which is called, from the parts on which it is diſtributed, the hypogaſtric, or internal iliac artery, is gradually bent forwards, and terminates like a ligamentous cord at the navel. The other artery is called the external iliac, and paſſes under the ligament of Fallopius, in its way to the lower extremity, on which it is diſtributed.

From the convex ſide of the curvature of the hypogaſtric artery are ſent off ſeveral conſiderable branches, which may be diſtinguiſhed by the following names; iliaca minor, ſacræ laterales, glutæa, ſciatica, pudica communis, hæmorrhoidalis media, obturatrix.

The iliaca minor is a ſmall artery, which is diſtributed on the iliac muſcles and bones. The arteriæ ſacræ laterales are commonly two in number. They are ſent to the fore part of the os ſacrum, and penetrating its ſubſtance, are diſtributed to the nerves and membranes within. The arteria glutæa is of very conſiderable ſize; it paſſes out of the pelvis with the ſciatic nerve, and is diſtributed on the two larger glutæi muſcles; it alſo gives branches to ſome other neighbouring muſcles, and to the parts about the anus. The arteria ſciatica gives ſome branches to the os ſacrum and adjoining muſcles. It paſſes obliquely over the ſciatic nerve, and goes through the great poſterior ſinus of the os ileum. It afterwards aſcends on the outſide of the os ileum, and is ſpent on that and the glutæi muſcles. The arteria pudica communis, or pudica interna, divides into two branches; one of theſe runs on the inſide of the tubercle of the iſchium to where the

corpora

corpora cavernosa take their origin; at this place it is divided into several smaller branches, which are distributed on the corpora cavernosa, the bulb of the urethra, and the anus. The second principal branch, sometimes called the pudica externa, runs between the bladder and rectum.

The hæmorrhoidalis media proceeds from the pudica interna, or some of the other large branches; it goes to the lower part of the rectum, and sends twigs to the bladder, vesiculæ seminales, and prostate gland. The arteria obturatrix perforates the obturator muscles, and is distributed to the neighbouring muscles.

The hypogastric, or internal iliac artery, having sent off all these branches to the parts about the pelvis, ascends on the side of the bladder towards the navel, where it meets its fellow of the opposite side. These arteries, near the navel, are in the adult contracted into the appearance of a ligament, and are quite closed; in the fœtus, however, they are a continuation of the trunk of the hypogastric arteries by which the circulation is carried on between it and the placenta.

It has been already mentioned, that the external iliac artery passes out of the abdomen under Fallopius's ligament; it here gives off two considerable branches; one of these, the arteria epigastrica, runs upwards on the muscles at the anterior part of the abdomen, and communicates freely with the mammaria interna; the other branch, sent off from the external iliac at this place, runs to the internal edge of the os ileum, and is ramified on the oblique and transverse muscles of the abdomen, communicating with the lumbar arteries.

After it has passed under the ligament of Fallopius, the external iliac changes its name to that of the crural or femoral artery. It sends off, first, three small branches; one, the pudica externa, goes to the inguinal

glands,

glands, &c. and communicates with the pudica interna; another goes to the pectineus muſcle; and the third, to the upper part of the ſartorius.

Afterwards the trunk of the artery deſcends to the head of the os femoris. About three fingers breadth from the ligament of Fallopius, it ſends out three conſiderable branches. The external branch, called the circumflexa externa, is diſtributed to the muſcles of the thigh, ſituated before and at the outſide. The middle branch, named the profunda, runs down on the inſide of the thigh between the triceps muſcles. The internal branch, called the circumflexa interna, runs backwards towards the great trochanter, and ſupplies the muſcles ſeated at the poſterior part of the os femoris, and ſends a branch into the ſubſtance of the bone itſelf.

After having ſent off theſe branches, the crural artery, covered by the ſartorius muſcle, proceeds down to the bottom of the thigh, and paſſes through the tendon of the adductor magnus, a little above the internal condyle of the os femoris; afterwards, continuing its courſe through the hollow of the ham, it is called the arteria poplitea.

While in the ham it ſends off branches, which aſcend to communicate with thoſe of the crural artery. Branches are alſo ſent to the joint. When it has reached the back part of the head of the tibia, it gives off two branches, one to each ſide. As the poplitea ends, it divides into two principal branches; one of which runs between the heads of the tibia and fibula, paſſing from behind forwards on the interoſſeous ligament, where it takes the name of arteria tibialis anterior; the ſecond branch divides into two others, the larger called arteria tibialis poſterior, the other arteria peronea poſterior.

From the anterior, ſuperior, or right ventricle of the heart proceeds an artery (the pulmonary) nearly equal

to the aorta, but the coats of which are leſs robuſt. Its trunk, having run upwards almoſt as high as the aorta, is divided into two parts, one of which paſſes under the aorta to the right lung, while the other proceeds to the left. Theſe arteries enter the lungs with the bronchia, and the diviſions and ſub-diviſions of both are diſtributed together through their ſubſtance. The ultimate ramifications of the pulmonary artery are ſpread out on the air-veſſels, through which the blood undergoes that change from the air which it is the purpoſe of reſpiration to effect.

Beſides receiving arteries in common with other parts of the body, we find that the lungs continually receive and return the ſame quantity of blood as paſſes through all the other parts of the body; from which we may form ſome idea of their extreme vaſcularity.

In the plate annexed (XII.) the arteries are repreſented freed from the muſcular and fibrous parts.

1. Aorta aſcendens.
A. Three ſemilunar valves.
2. Trunk of the coronary artery.
3. Aorta deſcendens.
4. Subclavian artery.
5.5. Carotid arteries.
6.6. Vertebral arteries.
7.7. Arteries that go to the lower part of the face, tongue, &c.
8.8. Temporal arteries.
10.10. Trunks which go to the foramina narium, &c.
11.11. Occipital arteries.
12.12. Arteries which go to the fauces, &c.
B.B. A ſmall portion of the baſis of the ſkull.
13.13. Contorſions of the carotid arteries, before they paſs to the brain.

C. The

C. The pituitary gland between the contorted trunks of

14.14. The carotid arteries.

D.D. The ophthalmic arteries.

15. Contorſions of the vertebrals.

16. The vertebral arteries, where they lie on the medulla oblongata.

18.18. Ramifications of the arteries within the ſkull.

E.E. The arteries of the cerebellum.

19.19. Arteries of the larynx, &c.

20.20. Arteries which convey blood to the muſcles of the neck and ſcapula.

21.21. Mammary arteries.

22,22. Arteries of the muſcles of the os humeri, &c.

23.24. Diviſions of the arteries of the arm.

25.25. A branch of an artery not found in all ſubjects.

26. External artery of the cubitus.

27. Arteries of the hands and fingers.

28.28. Diviſion of the aorta.

29. Bronchial artery.

31. Intercoſtal arteries.

32. Cœliac artery.

33. Hepatic arteries.

34. Arteria cyſtica, on the gall-bladder.

35. Lower coronary artery of the ſtomach.

36. Pyloric artery.

37. Epiploic artery.

38. Ramifications of the coronary artery, which embrace the bottom of the ſtomach.

39. The upper coronary artery of the ſtomach.

40.40. Phrenic arteries.

41. Splenic artery.

43. Upper meſenteric artery.

44. Superior

44. Superior branches of the meſenteric artery, freed from the ſmall inteſtines.

45. Lower meſenteric artery.

49.49. Emulgent arteries.

50. Arteriæ lumbares.

51. Spermatic arteries.

52. Arteria ſacra.

53.53. Common iliac arteries.

54.54. Iliacus externus.

55.55. Iliacus internus.

56.56. Umbilical arteries.

57.57. Epigaſtric arteries.

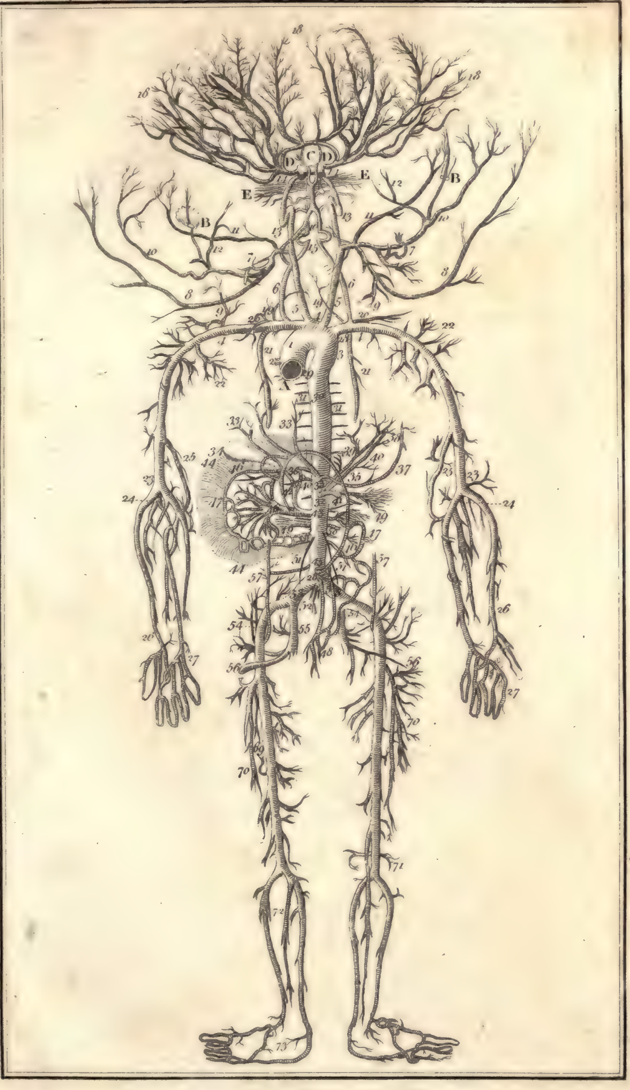
69. The crural artery.

70. Arteries which paſs to the muſcles of the thighs and tibiæ.

71. Part of the crural artery.

72. The three large trunks of the arteries of the leg.

73. Arteries of the foot.



CHAP. XXV.

GENERAL DISTRIBUTION OF THE VEINS.

Pulmonary Veins.—Vena Cava.—Veins of the Head,—Jugular and Subclavian.—Veins of the Superior Extremity.—Vena Azygos.—Veins of the Lower Extremities.—Course of the Blood through the abdominal Viscera, the Liver, &c.

IN describing the arteries we followed the course of the blood, and beginning with the largest trunks, traced the several branches in the order in which they were sent off. In pointing out the course of the veins, however, and still following the course of their contents, the order of the description will necessarily be reversed, as it is necessary, in this case, to begin with the ramifications, and trace them into the trunks.

The veins of the body may be divided into two classes; those which return the blood conveyed by the pulmonary artery, and those which return that of the aorta.

It has been already remarked, that, besides the blood which the lungs receive in common with other parts of the body, they also receive all that is transmitted by the pulmonary artery. This, after being distributed through the substance of the lungs, is returned by veins, which at length unite into four trunks, and passing through the pericardium, are inserted into the posterior auricle of the heart.

The blood, which is sent to the various parts of the body by the aorta is ultimately received and returned by two large trunks, the vena cava superior and inferior, which enter the anterior auricle of the heart. I shall

ſhall now proceed to enumerate, in a curſory manner, the branches by which theſe trunks are ſupplied.

In treating of the brain, I ſhall endeavour to deſcribe more fully the triangular canals, called ſinuſes, ſituated in the dura mater, and which perform the office of veins. The vena cava ſuperior is formed in the following manner. The blood, which is ſent to the internal parts of the head, after paſſing through other veins and ſinuſes is received by the two lateral ſinuſes; theſe terminate in the internal jugular veins, which correſpond with the internal carotid artery, and terminate in the ſubclavian vein. The external jugular vein, which correſponds with the external carotid artery, receives the blood from the external parts of the head, and alſo terminates in the ſubclavian vein. This vein alſo receives the contents of the vertebral vein, which correſponds with the artery of the ſame name.

The veins of the ſuperior extremities run in two ſets; ſome of them lie immediately under the ſkin, others are deeply ſeated, and accompany the arteries. The vena baſilica is formed by a number of branches; it proceeds immediately under the ſkin, along the courſe of the ulna, to the internal condyle of the os humeri. It afterwards runs up along the inſide of the arm, communicating freely both with the deep and ſuperficial veins. The vena cephalica receives, at the extremity of the radius, branches which correſpond with thoſe of the radial artery. The trunk runs along the radius, between the muſcles and integuments, communicating with all the neighbouring veins; having paſſed the fold of the arm, it aſcends near the outer edge of the external portion of the biceps, ſtill communicating with the other veins, and paſſing between the large pectoral and deltoid muſcles, terminates, as well as the baſilica, in the trunk of the axillary vein.

The

The vena axillaris, which correſponds with the artery of the ſame name, is formed by all the veins of the ſuperior extremity. Above the axilla it receives branches from all the muſcles ſituated about the ſcapula, and the upper part of the thorax. Where it paſſes between the clavicle and firſt rib, it changes its name from that of the axillary vein to that of the ſubclavian. The ſubclavian veins, receive the contents of the jugular and vertebral veins which come from the head, and alſo other branches from adjoining parts. The left ſubclavian vein alſo receives a particular vein, called the intercoſtalis ſuperior, which proceeds from the upper intercoſtal muſcles of that ſide. The left ſubclavian vein alſo receives the contents of the thoracic duct, which is deſcribed in another place.

The two ſubclavian veins are directed towards each other, and uniting in the upper part of the thorax, rather towards the right ſide, conſtitute the vena cava ſuperior. Into the upper part of the vena cava opens a vein of conſiderable ſize, called the vena azygos, or the vein without a fellow. This ariſes from the lower and internal part of the thorax, and ſoon paſſes over to the right part of the ſpine. As it aſcends along the right ſide of the thorax, it receives the inferior intercoſtal veins of that ſide, and higher up a trunk common to two or three veins, which alſo come from the intercoſtals. At the top of the thorax it is bent forwards over the right lung, and opens into the vena cava a little above the pericardium. The vena cava now perforates the pericardium, and deſcends to the anterior or right auricle of the heart.

The veins of the lower extremities, which terminate in the vena cava inferior, are

The vena ſaphena major, which begins on the inſide of the foot, at the great toe, and runs to the inner ankle;

here it receives other branches, and then runs up the inſide of the tibia, immediately under the ſkin. After communicating freely, and receiving other branches, the ſaphena paſſes along the inſide of the knee, and afterwards along the thigh as far as the middle of the ſartorius muſcle; it next runs on the fore part of the thigh to the groin, and at length opens into the top of the femoral vein. As this vein is quite ſuperficial, it may be traced through the whole of its progreſs, when it is diſtended with blood, by the naked eye.

The vena ſaphena minor returns the blood from the outer ſide of the foot; from this part it runs up on the outſide of the tendo Achillis, and next between the gaſtrocnemius externus and the ſkin. It terminates in the vena poplitea a little above the ham.

The vena tibialis anterior is a trunk which accompanies the artery of the ſame name, and terminates in the vena poplitea.

The vena tibialis poſterior begins from the ſole of the foot by ſeveral branches. Theſe, forming a trunk, run on the inner ſide of the os calcis, and behind the inner ankle. It paſſes up between the ſoleus, and tibialis poſticus muſcles, accompanied by the correſponding artery, and opens into the vena poplitea.

The vena peronea proceeds upwards along the inſide of the fibula, almoſt in the ſame direction with the arteria peronea, and alſo ends in the vena poplitea.

The vena poplitea, which correſponds with the artery of the ſame name, is formed by the three large veins deſcribed, but ſeems to be a continuation of the tibialis poſterior. The vena poplitea runs up immediately on the muſcle of the ſame name. About the ham it receives a number of branches from the joint and from the neighbouring muſcles. A little above the ham it receives the name of the crural vein, which

takes

takes its courſe upwards between the biceps and other flexors of the leg, cloſely accompanied by the crural artery. When it has arrived oppoſite the trochanter minor it receives three conſiderable veins, the circumflexa interna, externa, and profunda, which correſpond with the arteries of the ſame names. About an inch below the ligament of Fallopius, it receives the vena ſaphena major, the courſe of which has already been deſcribed. About this place it alſo receives the venæ pudicæ externæ.

After paſſing under the ligament of Fallopius, and entering the pelvis, it changes its name to that of the external iliac vein. It now receives the vena epigaſtrica, which deſcends towards it at the anterior part of the abdomen, and other venous branches from the adjacent parts. After having received the venous branches which correſpond with the arterial branches of the external iliac artery, the external iliac vein unites with the trunk of the internal iliac, or hypogaſtric, vein, which returns the blood ſent to the pelvis by the artery of the ſame name. Theſe two venous trunks uniting, form the vena iliaca communis, and the iliacæ communes of both ſides uniting, form the inferior vena cava. This aſcends on the vertebræ but inclines towards the right ſide, whereas the aorta is placed towards the left. It receives the venæ lumbares, which enter it behind in pairs. Higher up it is joined by the emulgent veins from the kidneys, the venæ capſulares from the glandulæ ſuprarenales, and by the right ſpermatic vein. The left ſpermatic vein commonly goes into the emulgent vein of the ſame ſide. Oppoſite the liver the vena cava receives the blood from the diaphragm and pericardium. Hitherto, none of the veins which return the blood ſent to the abdominal viſcera by the cæliac and the two meſenteric arteries have

been noticed. The courſe of this blood, however, deſerves particular attention.

The veins of the rectum form the beginning of a vein called vena meſeraica minor, or vena hæmorrhoidalis interna. This afterwards unites with a branch from the left part of the arch of the colon, and opens at length into the vena ſplenica.

The vena ſplenica returns the blood from the ſpleen, and in its paſſage alſo receives branches from the ſtomach, pancreas, and omentum, and alſo the vena meſeraica minor laſt deſcribed.

The vena meſeraica major returns the blood of moſt of the branches of the arteria meſenterica ſuperior, which are diſtributed on the ſmall inteſtines and right portion of the colon. It alſo receives the vena cæcalis from the beginning of the colon, the gaſtro colica, partly from the ſtomach and partly from the colon, and ſome other branches from the adjoining viſcera, which vary in different ſubjects.

The vena ſplenica receives the vena meſeraica minor, and the vena meſeraica major the vena ſplenica, and thus is brought into one veſſel, called the vena portæ, the blood which comes from the omentum, the pancreas, the ſpleen, the ſtomach, and the ſmall and great inteſtines. The blood, however, thus collected, is not immediately returned to the heart, as in other parts of the body; for the vena portæ, having arrived at the concave part of the liver, is firſt divided into five branches, and theſe into others more minute, which are diſtributed through that organ like arteries, and which perform the ſecretion of the bile. Where the vena portæ enters the liver, its ſtructure becomes more robuſt, to enable it to perform its new office. The blood, thus circulated through the liver, is again collected by another ſet of veins, which,

uniting

uniting into two or three principal trunks, called venæ hepaticæ, pour their contents into the vena cava. The vena cava afcendens, having received thefe veins, perforates the diaphragm and pericardium, and meeting with the fuperior cava, they empty themfelves together into the anterior auricle.

The veins are reprefented in plate XIII. though not fo perfectly as I could have wifhed.

aa. Vena cava.
b. Defcending trunk of the cava.
c.c. Afcending trunk of the cava.
d.d. Subclavian veins.
e. Vena azygos.
f. Intercoftal veins.
g. Mammary veins.
i.i. Internal jugulars.
l.l. External jugulars.
m. Right axillary vein.
n. Cephalic vein.
o. Bafilic.
q. Phrenic.
s.s. Emulgents.
w.w. Iliac branches.
x. Internal iliacs.
1. Vena facra.
2. Spermatic veins.
3. Epigaftric.
4. Saphena.

Chap. XXVI.

STRUCTURE AND COURSE OF THE LYMPHATICS.

Two Kinds of Lymphatics.—Description of these Vessels.—Lymphatic Glands.—Lacteals.—Thoracic Duct.—Receptacle of the Chyle, &c.

LYMPHATICS are small pellucid vessels, which convey fluids perfectly, or very nearly, colourless. The lymphatics are of two kinds; those which take up fluids from the body in general, and those which receive the digested aliment from the intestines. The latter kind are called lacteals, and both of them terminate in a common trunk, the thoracic duct.

The lymphatics have at least two coats, which are thin and transparent, but tolerably strong. They have also nerves and muscular fibres, as may be collected from their sensibility when inflamed, and from their power of contraction. They are furnished with valves, which are placed in pairs, and which are so numerous, that three or four of them often occur within the distance of one inch. From this circumstance they are frequently called valvular lymphatic vessels, to distinguish them from the minute ramifications of the sanguiferous system, which also convey a colourless fluid.

Lymphatics begin by extremely minute tubes from the whole surface of the body, from the cellular substance, from the cavities of the body, from all the glands, from all the viscera, and in general from every part of the system.

It

It is now well aſcertained, that not only water is abſorbed by the lymphatics on the ſurface of the body, but many other ſubſtances. No lymphatics have been demonſtrated in the brain; but from a variety of circumſtances there can be very little doubt of their exiſtence.

All the lymphatics of the body paſs through certain glands, which are connected with them. When the lymphatics approach theſe glands, they ſend ſome branches to neighbouring lymphatics; other branches paſs over the ſurface of the glands, and others enter their ſubſtance, in which they are ſo minutely divided as to eſcape obſervation. A great number of theſe glands are placed at the upper part of the thigh, belonging to the lymphatics of the lower extremity; others are placed under the arm, belonging to thoſe of the upper; and there are ſimilar glands about the neck, and in various other parts of the body. It is at preſent diſputed among anatomiſts, whether lymphatic glands are formed of cells or convoluted veſſels; but the latter opinion ſeems to be more probable. Lymphatic or conglobate glands are of various ſizes, from that of a ſmall pea to that of a bean. They are commonly ſomewhat flattened. In young ſubjects they are found of a reddiſh or brown colour, but they become whiter in the progreſs of life. Their ſurface is ſhining, which is owing to a ſmooth denſe coat with which they are covered. Theſe glands are ſaid to be wanting in ſome animals, which yet have lymphatic veſſels.

The lacteals are ſo called from a degree of whiteneſs in their appearance like that of milk, which they receive from the colour of the fluid they convey. They ariſe from the villous coat both of the great and ſmall inteſtines, but principally from the ſmall,

 particularly

parricularly the jejunum; paffing in their courfe through conglobate glands, they advance between the laminæ of the mefentery towards the fecond or third lumbar vertebra, where they meet with the lymphatics of the lower extremities.

Of thefe fome are fuperficial, and others deeply feated. The former chiefly lie at the infide of the leg and thigh, and follow the courfe of the vena faphena major. In the groin they pafs through lymphatic glands. Being joined by the lymphatics of the lower part of the abdomen, they pafs under the ligament of Fallopius. The lymphatics of the lower extremities and pelvis, and the lacteals from the inteftines, form the beginning of the thoracic duct. This veffel alfo receives the lymph from the other abdominal vifcera.

The thoracic duct, fo called from its courfe through the thorax, ufually begins about the fecond or third lumbar vertebra. It is of different fizes in different fubjects, and is fometimes extended at its lower part into a pyriform bag, called the receptaculum chyli; but in general there is no enlargement fo remarkable as to deferve a particular name. The thoracic duct fometimes divides and again unites. At its beginning, it is fituated at the right fide of the aorta. It is afterwards obferved in the thorax, lying between the aorta and vena azygos. It afcends as high as the fixth vertebra of the neck, where, forming an arch, it turns downwards and enters the left fubclavian vein near the infertion of the internal jugular.

The thoracic duct is furnifhed with few valves, and thefe are placed without much regularity. At the place, however, where it is inferted into the fubclavian vein, there is a circular valve, which prevents the blood from getting into it.

Befides

Besides the thoracic duct, which receives the lymph from the lower extremities and the left side, and the chyle from the intestines, there is another vessel somewhat similar, but much shorter, on the right side. This receives the lymphatics from the right arm, the right lung, and the right side of the head, and enters the right subclavian vein at the same place where the thoracic duct enters the left.

Chap. XXVII.

OF THE BRAIN, &c.

The Dura Mater.—The Falx.—Sinuſes of the Brain.—The Pia Mater.—The Cerebrum and Cerebellum.— Source of the Optic Nerves.—The Pineal Gland.—The ſuppoſed Seat of the Soul.— The Medulla Oblongata.—Source of the Nerves.—The Spinal Marrow.

THE cavity of the cranium is every way ſurrounded with ſtrong bones, which have been already deſcribed. Within theſe, before we arrive at the ſubſtance of the brain, we meet with two membranes, called by the antients the dura and pia mater, from an opinion that they were the ſource of the other membranes of the body. The ſame names are ſtill applied to them by the moderns, though, as in many other caſes, the opinion which gave riſe to them is exploded.

The dura mater is a thick, firm, inſenſible membrane, extremely full of blood veſſels. Its external ſurface performs the part of a perioſteum to the internal part of the ſkull, to which it adheres by numerous blood veſſels, particularly at the ſutures, where they paſs through the cranium to communicate with thoſe of the external perioſteum. Its internal ſurface is moiſtened by the exhalation of a thin fluid, which prevents its adheſion to the membrane within.

The dura mater forms ſeveral projections, which ſerve very important purpoſes. One of theſe, from its reſemblance to the blade of a ſcythe, is called the falx. Its narroweſt end is attached to the criſta galli

of the ethmoid bone; it runs backwards along the courſe of the ſagittal ſuture, to where it meets with the lambdoidal. A little below the lambdoidal ſuture it divides into two wings, forming a tranſverſe ſeptum, which is firmly attached behind to the os occipitis. The uſe of the falx is to divide the brain into its two hemiſpheres, and to ſupport them, and prevent their preſſing on each other when the head is turned to either ſide. The tranſverſe ſeptum divides the great brain or cerebrum from the ſmaller brain or cerebellum, the former being placed above it, the latter below. It alſo ſupports the cerebrum, and prevents it from gravitating on the cerebellum when the body is in the erect poſture. The connection between the tranſverſe ſeptum and the falx is ſuch, that they preſerve each other in a ſtate of tenſion, for if either of them is cut after the contents of the cranium are removed, the other immediately becomes relaxed and flaccid. Below the tranſverſe ſeptum is ſituated a ſmaller falx, which ſerves the ſame purpoſes in the cerebellum as the great falx does in the cerebrum. In the tranſverſe ſeptum is a great oval notch, through which the ſubſtance of the cerebrum and cerebellum communicate and are intimately mixed.

Both the membranes of the brain paſs out of the cranium with the trunks of nerves, and afford them coverings, till they terminate in their ſentient extremities.

The blood which is circulated through the brain is not returned through ſuch veins as are found in other parts of the body. We here obſerve a peculiar kind of canals called ſinuſes, which are contained in the duplicatures of the dura mater. The moſt remarkable of theſe is the longitudinal, which runs in the upper part of the falx; at the tranſverſe ſeptum this divides

into

into two others, called lateral ſinuſes, which, paſſing through the baſe of the cranium, terminate in the jugular veins. Near the concourſe of the ſuperior and lateral ſinuſes, we obſerve an opening, which is the orifice of a ſinus, ſituated along the union of the falx and tranſverſe ſeptum.

Theſe ſinuſes are triangular veins, which, being conveyed through ſo firm a membrane as the dura mater, are much leſs liable to be ruptured or diſtended; theſe accidents are ſtill further guarded againſt by certain filaments, which paſs from one ſide of the ſinuſes to the other, and give ſtill further ſecurity againſt the bad effects which are found to ariſe from the preſſure of the brain. The veins, which pour their blood into the ſinuſes, enter them in ſuch a manner as to produce the effect of a valve, and to prevent the blood from returning into the tender veſſels of the brain, and thus over-diſtending them.

Beſides the ſinuſes above-mentioned there are others of a ſmaller ſize, which anſwer the ſame important purpoſes. All theſe communicate with each other and with the great lateral ſinuſes, and therefore diſcharge their blood into the internal jugular veins.

The cavernous or lateral ſinuſes of the os ſphenoides are reſervoirs of a particular kind, containing conſiderable veſſels and nerves; and likewiſe a cavernous and ſpongy ſtructure, which for ſome unknown purpoſe is conſtantly filled with blood.

The pia mater is a much ſofter and thinner membrane than the former; it is connected to the dura mater only by the veins which open into the ſinuſes. The pia mater conſiſts of two laminæ; the external of theſe, from its extreme thinneſs, has been compared to the ſpider's web, and is named tunica arachnoidea; at the upper part of the brain it is connected both to the

the dura mater and the internal lamina of the pia mater, by means of blood-veſſels, but in other parts it is quite ſeparate from both. It is ſpread uniformly over the ſurface of the brain, incloſing all the convolutions, but not entering between any of them.

On the contrary, the internal and moſt conſiderable lamina of the pia mater is not only inſinuated into the numerous folds and circumvolutions of the brain, but is continued into its cavities, performing the important office of conveying the blood-veſſels to that delicate organ in ſuch a minute ſtate of diviſion, that their pulſation cannot be prejudicial to its functions.

The brain completely fills the cavity of the cranium, and its form therefore correſponds with it; it is convex above, irregular below, and flat at the ſides. Under the general name of brain, or encephalon, are included the cerebrum, which occupies the upper and largeſt portion of the cranium, and the cerebellum, which is ſeated in its lower and poſterior part, under the tranſverſe ſeptum. The cerebrum is divided longitudinally at its upper part, by the falx, into its two hemiſpheres. The irregular ſurface of the cranium below divides each hemiſphere into three lobes. The anterior lobe is lodged on the orbital proceſſes of the os frontis; the middle lobe lies in the middle foſſæ of the baſis of the cranium; the poſterior reſts on the tranſverſe ſeptum over the cerebellum. The cerebellum is itſelf divided into two hemiſpheres by the ſmall falx.

The component matter of the brain is of two kinds; a greyiſh matter, which is for the moſt part placed without, and is therefore called the cortical, and a white matter called the medullary, which is generally ſituated within. The cortical part chiefly accompanies the convolutions of the brain; the medullary is entire, and ſeems

ſeems to be compoſed of numerous white, minute, parallel, and very tender fibres.

Having removed the falx from between the hemiſpheres of the brain, and drawn them gently from each other, we obſerve below a white convex ſurface, which is part of what is called the corpus calloſum. It is a middle portion of the medullary ſubſtance, which, under the inferior edge of the falx, and for ſome diſtance on each ſide, is parted from the maſs of the cerebrum by a fold of the pia mater. Along the middle of the ſurface of the corpus calloſum, a kind of ſuture is formed by a particular intertexture of fibres croſſing each other. Immediately under theſe is placed the ſeptum lucidum, which is connected below to the fornix, and divides the anterior ventricles of the brain from each other. Theſe ventricles are diſcovered by making an horizontal inciſion in the brain, on a level with the corpus calloſum. When we have cut into them, we find that they are narrow canals, which take a very winding courſe through the ſubſtance of the brain. They are lined with the pia mater, and contain a curious collection of minute blood veſſels twiſted about each other, and called plexus choroides. One of the anterior ventricles is ſituated in each hemiſphere of the brain, and they are divided from each other by the ſeptum lucidum.

The ſeptum lucidum is united by its lower part to the anterior portion of that medullary body called the fornix, which forms a kind of arch, ſituated under the corpus calloſum, and is nearly of a triangular ſhape. At the anterior part the fornix ſends off a double medullary cord, called its anterior crura; immediately below which we obſerve a large white medullary rope ſtretched tranſverſely between the two hemiſpheres, and commonly called the anterior commiſſure of the

cerebrum.

cerebrum. To this ſubſtance the ſeptum lucidum is connected. At the poſterior part of the fornix are two other crura, which unite with two medullary protuberances called pedes hippocampi. Under the fornix, and immediately behind its anterior crura, there is a hole by which the two anterior ventricles communicate. In examining the ſubſtance of the cerebrum, the deeper we go towards the baſis of the cranium, we find that the medullary part becomes the broader.

The plexus choroides is a very fine vaſcular texture, conſiſting of a great number of arterial and venal ramifications, ſpread over the lateral or anterior ventricles. When we have removed this plexus, we diſcover ſeveral protuberances included in theſe cavities. Theſe are the corpora ſtriata, the thalami nervorum opticorum, and the nates and teſtes.

The corpora ſtriata are two curved oblong eminences, which extend along the anterior part of the lateral ventricles. They are called ſtriata or ſtriped, becauſe in cutting them we meet with a number of white and aſh coloured lines alternately diſpoſed. Theſe two eminences are of a greyiſh colour on the ſurface, and larger before than behind, where they are narrow and bent. They may be conſidered as forming the convex baſes of the ventricles.

The thalami nervorum opticorum are externally white, but alſo contain both cortical and medullary ſubſtance, and derive their name from being the chief ſource of the optic nerves. They are two eminences placed near each other, between the poſterior portions or extremities of the corpora ſtriata. They are cloſely united, and at their convex part form one body. Immediately under the union of the thalami nervorum opticorum lies a cavity, called the third ventricle of the cerebrum. This cavity communicates at its upper and

fore

fore part with the passage between the two lateral ventricles, and sends down from its under and fore part a passage through the infundibulum; it has a communication backwards with the fourth ventricle.

The infundibulum is a small medullary canal, situated between the base of the anterior pillar of the fornix, and the anterior part of the union of the thalami nervorum opticorum. It runs downwards, and terminates by a small membranous canal in a softish body, situated in the sella turcica of the sphenoidal bone, and called glandula pituitaria. This substance was so named by the ancients, from its supposed office of cleansing the brain from serous fluids. Its real use is wholly unknown. In ruminant animals it is much larger than in man.

The nates and testes, or as they are otherwise denominated, tubercula quadrigemina, are four tubercles, situated behind the union of the thalami nervorum opticorum, adhering to each other. They are externally white, and their internal substance is greyish. Between the two anterior tubercles and the convex part of the thalami nervorum opticorum is an interstice called foramen commune posterius. This, however, is closed by the pia mater, and does not open into any cavity.

Above the tubercula quadrigemina, and behind the thalami nervorum opticorum, is fixed the pineal gland. This body is of an oval form, about the size of a pea, and is connected to the lower part of the thalami by two very white medullary pedunculi. It seems to be mostly formed of cortical substance, particularly at its upper part, and adheres closely to the plexus choroides, with which it is covered. This small body has been rendered famous by Descartes, who supposed it to be the seat of the soul. It is often found, on being cut into,

into, to contain a gravelly ſubſtance, which reſiſts the knife. Below the pineal gland there is a tranſverſe medullary cord, called the poſterior commiſſure of the hemiſpheres of the cranium.

The cerebellum is ſituated under the tranſverſe ſeptum, in the poſterior and lower part of the cranium. Like the cerebrum it is compoſed of cineritious and medullary matter. It differs from the cerebrum, however, in having no circumvolutions on its ſurface; inſtead of theſe, we here obſerve numerous furrows running parallel to each other, and nearly in a tranſverſe direction, into which enter folds of the pia mater. Under the tranſverſe ſeptum it is covered by a vaſcular texture which communicates with the plexus choroides. It has four eminences which are turned in different directions, and which from ſome reſemblance to the rings of an earth-worm are named appendices vermiformes. The cerebellum is divided into two lateral parts by the ſmall falx; on the back part it is divided into two lobes ſeparated by the occipital ſeptum of the dura mater.

By cutting deeply into the ſubſtance of the cerebellum in the direction of its falx, we obſerve an oblong cavity which is called the fourth ventricle; this terminates backwards like the point of a writing-pen, and this end of it has therefore been called calamus ſcriptorius. At the beginning of this cavity we meet with a thin medullary lamina which has been conſidered as a valve. This ventricle is lined like the others with the pia mater, which is continued through all theſe cavities.

The ſubſtance of the cerebellum appears very different, according to the direction in which it is cut. By dividing it vertically we find the medullary part diſpoſed ſo as to exhibit the appearance of a tree.

Theſe ramifications unite to form a medullary trunk; the middle, anterior, and moſt conſiderable part of which forms two proceſſes, the crura cerebelli, which uniting with the crura cerebri conſtitute the medulla oblongata, which will be next deſcribed; when the cerebellum is cut horizontally this appearance is entirely loſt.

The medulla oblongata is ſituated in the lower and poſterior part of the cranium, and is formed of two conſiderable medullary proceſſes of the cerebellum, and of the two larger proceſſes of the cerebrum called their crura. It may therefore be conſidered as a medullary maſs common to both cerebrum and cerebellum, by the reciprocal continuity of their ſubſtances through the great notch in the tranſverſe ſeptum. The medulla oblongata can only be ſeen when removed from the cranium, and the deſcription can only apply to the parts when viewed in their inverted ſituation.

The crura cerebri ariſe from the middle and lower part of each hemiſphere. Where they ariſe from the cerebrum they are ſeparate, but converge as they run backwards ſo as to reſemble the letter V. Where they unite they form a middle tranſverſe protuberance called the pons Varolii, becauſe that anatomiſt compared it to a bridge, and the two crura cerebri to two rivers. This compariſon, however, conveys no idea of the real appearance of the parts, and the pons Varolii is to be conſidered merely as an eminence formed by the union of the crura of the cerebrum and cerebellum.

Between the crura cerebri and near the anterior edge of the pons Varolii are two white eminences, named eminentiæ mamillares. From the poſterior part of the pons Varolii the medulla oblongata is contracted, and deſcends obliquely backwards to the foramen magnum of the os occipitis, where it terminates in the

 medulla

medulla ſpinalis. In this part of it ſeveral appearances are to be noticed. We obſerve four eminences, two named the corpora olivaria, and the other two the corpora pyramidalia. Immediately behind theſe we diſcover the beginning of two grooves, one above and one below. Theſe becoming deeper divide the medulla oblongata into two cylinders. When we ſeparate theſe with the fingers we obſerve ſeveral medullary cords which croſs each other in paſſing from one lateral portion to the other.

The corpora olivaria and pyramidalia are whitiſh eminences ſituated longitudinally near each other immediately behind the pons Varolii. The corpora olivaria are outermoſt and are nearly of an oval ſhape. Between them are the corpora pyramidalia, each of which terminates in a point.

It is obſervable, in general, with reſpect to the eminences of the medulla oblongata, that thoſe which are medullary without are chiefly cortical within. What are the diſtinct functions of theſe ſubſtances which appear ſo different to the eye, and what purpoſes are anſwered by their intermixture, are points which muſt remain undetermined till we can diſcover the connection between the mind and the body, and enter into the ſecret mechaniſm of this wonderful engine of ſenſation and intellect.

The brain of birds is covered with the common membranes, but its external ſurface is not formed into ſo many gyræ or convolutions as ours. Its anterior part is quite ſolid, of a cineritious colour, and ſo far has a reſemblance of the corpora ſtriata as to give riſe to the olfactory nerves. The whole of it appears to us imperfect, and we can ſcarcely diſtinguiſh whether there is any thing analogous to a third or fourth ventricle: neither the *corpus calloſum*, *fornix*, *nates* nor *teſtes*,

 can

can be obſerved here: which parts therefore cannot be conſidered as neceſſary to the functions of life; we might, however, be led to imagine, that they are ſubſervient to the ſuperior intellectual powers of the human mind, did we not find that quadrupeds have theſe parts as well as men. Theſe appearances ſeem rather to depend on the various diſpoſition and direction of the fibres which compoſe the brain; and the particular uſes which have been aſſigned to the different parts of the brain ſeem to have no other foundation than the fancy of authors, who have indulged themſelves in fruitleſs ſpeculations. Thoſe birds which ſeek their food below the ſurface of water, mud, &c. have large nerves which run quite to the extremity of the bill, by which the ſenſation of that part is rendered more acute.

From the medulla oblongata, which is formed by the union of the cerebrum and cerebellum, ariſe not only the ſpinal marrow, but almoſt all the other nerves which perforate the baſe of the cranium.

The medulla ſpinalis, or ſpinal marrow, is a continuation of the medulla oblongata, which paſſes through the great foramen of the cranium, and is continued down the bony canal formed by the vertebræ. The figure of the ſpinal marrow is compreſſed, being flatter behind than before, where we obſerve a continuation of thoſe grooves which divide the medulla oblongata into its lateral portions. In the medulla ſpinalis theſe appear like two cords cloſely applied to each other, but which may be eaſily ſeparated both before and behind till we come to their middle, where they are joined together by a thin layer of cineritious ſubſtance paſſing from one cord into the other. The ſpinal marrow, like the parts of which it is a continuation, conſiſts of medullary and cineritious ſubſtance; the former, however,

ever, is here placed without; the cineritious is placed within, and by a tranſverſe ſection of the medulla ſpinalis it appears to be in the form of a horſe-ſhoe, the convex ſide of which is turned forwards and its extremities backward.

The ſpinal marrow is inveſted both with the dura and pia mater. The former of theſe in paſſing out of the foramen of the os occipitis, forms a kind of funnel, adhering at its upper part to the ligamentary ſubſtance which lines the bony canal of the vertebræ. Lower down there is no adheſion, except where the nerves paſs through the notches of the ſpine, where the dura mater, which inveſts the medulla ſpinalis, ſends out on each ſide the ſame number of ſheaths as there are ganglions and nervous trunks.

The pia mater is connected with the dura mater by means of a thin tranſparent ſubſtance, which from its indentations between the ſpinal nerves has been named the ligamentum denticulatum. Its uſe is to ſupport the medulla ſpinalis, that it may not affect the medulla oblongata, or ſpinal nerves by its weight. The lower end of the ligamentum denticulatum runs to the os coccygis far below the termination of the ſpinal marrow.

Each lateral portion of the medulla ſpinalis ſends off, both from the fore and back parts, flat faſciculi of nervous fibres. The anterior and poſterior faſciculi are ſeparated from each other by the ligamentum denticulatum; then paſſing outwards they proceed through the dura mater by two diſtinct openings very near each other. Having penetrated the dura mater, the poſterior bundle forms a ganglion, from the oppoſite end of which the trunk comes out again, and is there joined by the anterior bundle.

The membrana arachnoides is here very diſtinct

from the internal lamina of the pia mater; ſo that by blowing through a hole made in the arachnoides, it will ſwell from one end to the other like a tranſparent inteſtine.

The ſpinal marrow gives riſe to about thirty pair of nerves. Thoſe which come out between the vertebræ of the neck are thinner than the reſt, and are placed almoſt tranſverſely; as we deſcend, we find them running more and more obliquely downwards, and when we arrive at the ſecond vertebra of the loins, the ſpinal marrow is ſplit into numerous thread-like fibres, and from its appearance is called cauda equina, or the horſe's tail. The nerves which ariſe from the different parts of the brain and ſpinal marrow will be treated of in a ſeparate chapter.

CHAP. XXVIII.

STRUCTURE AND GENERAL DISTRIBUTION OF THE NERVES.

Origin of the Nerves.—Extreme ſubtilty of the Nervous Fibres.—Ganglions.—Plexus.—Fontana's Microſcopical Obſervations on Nerves.—Nerves from the Brain.—Olfactory and Optic Nerves, &c.—Auditory Nerves, &c.—Lingual Nerves, &c.—Sympathetic Nerve.—Nerves from the Spinal Marrow.—Phrenic Nerve.—Dorſal and Brachial Nerves, &c.—Lumbar and Crural Nerves, &c.—Sciatic Nerve.

NERVES are white cords diſtributed from the brain over the whole body; they riſe, as was intimated in the preceding chapter, either immediately from the brain, or mediately from it by means of the ſpinal marrow, which is itſelf a continuation of the fibres of the brain, and might without impropriety be conſidered as the largeſt nerve in the body. The nerves, as they paſs off from the brain and ſpinal marrow are inveſted, and collected into firm cords, by the dura and pia mater. The former, however, is ſoon reflected back, but the latter accompanies them through all their ramifications, and is ſuppoſed to be only thrown aſide where they terminate in their ſentient extremities.

As the medullary fibres are obſerved to decuſſate each other in different parts of the brain, and as injuries of one ſide of the head have often been obſerved to produce a palſy of the oppoſite ſide of the body, it has been ſuppoſed that all the nerves originate from the ſide of the brain oppoſite to that at which they come out. This opinion, however, is far from being eſta-

 bliſhed,

bliſhed, becauſe a decuſſation in ſome parts is by no means a proof that it obtains univerſally; and though there are inſtances of injuries of the head, which have produced a palſy of the oppoſite ſide, there are others in which the injury and palſy were both on the ſame ſide.

Nerves are compoſed of threads of the ſmallneſs ot which we have probably no adequate idea. To aſſiſt us in forming one, we muſt conſider how uniformly nerves are diſtributed to even the moſt minute fibre of the body, and yet were they all conjoined, they would not make a cord of an inch diameter. It is deuuced from actual obſervation, that each fibre in the retina of the eye, or expanded optic nerve, cannot exceed in diameter the thirty-two thouſand four hundredth part of a hair.

Different nerves in their courſe often meet together, and form oblong reddiſh maſſes, called ganglions, larger than the nerves which form them, and alſo of a firmer conſiſtence. Within the ganglions the fibres of the nerves ſeem to be thoroughly mixed, and to approach more nearly to the nature of medullary matter. By ſome phyſiologiſts ganglions are ſuppoſed to be ſmall brains, whence the nerves acquire new power and energy. Others, obſerving that the nerves which ſupply the muſcles of involuntary motion, as thoſe of the heart and inteſtines, are particularly ſupplied with ganglions, have conſidered them as deſigned to intercept the operation of the will. Their real uſe is unknown to us, but from whatever cauſe it may happen, the nerves which proceed from a ganglion are rather larger than the ſum of thoſe which form it.

Several nerves frequently meet together, and by numerous junctions produce an appearance ſimilar to that of net-work, and this is called a plexus.

Nervous

Nervous cords have very little elaſticity compared with ſome other parts of the body.

The Abbè Fontana has taken great pains to aſcertain the primitive ſtructure of nerves. On examining a number of nerves with microſcopes of low powers, ſo as not to magnify more than four or five diameters, they always appeared to be ſurrounded with white ſpiral bands not unlike the effect which would be produced by a ribbon twiſted round a cylinder. The ſpiral bands were ſometimes perfectly regular, ſo as to be of equal width along the whole length of the nerve examined, and to leave a ſpace of a leſs bright colour of the ſame width between them; at other times they were irregular and croſſed each other at uncertain diſtances; this latter appearance, however, was found on further examination to proceed from the nerve ſubmitted to examination being compoſed of many others: for where he carefully ſeparated a nerve from thoſe which adhered to it, and examined it by itſelf, he always found the ſpiral bands regular. He ſaw theſe appearances very plainly in nerves not larger than a hair, with lenſes of very ſmall power, and was therefore perſuaded that this appearance of bands was not an optical illuſion.

The ſame nerve, however, which to the naked eye, and by a lens of ſmall power exhibited this appearance, when examined by a microſcope of high powers, appeared to conſiſt merely of parallel but twiſting fibres.

He next removed the cellular tiſſue or ſheath of a nerve, without injuring its texture; but ſtill with a microſcope of high powers he could perceive nothing but waving and twiſting fibres, and nothing but ſpiral bands with the naked eye. After applying, however, to theſe obſervations for two or three days, he found, that by merely moving the reflecting mirror, he ſometimes ſaw twiſting

twiſting fibres and ſometimes ſpiral bands with the ſame lens. He is therefore under a neceſſity of giving up his ſuppoſed diſcovery, and of allowing that the ſpiral bands were merely an optical deception.

From his obſervations he can deduce no more than that nerves are formed of a great number of tranſparent, homogeneous, uniform, and very ſimple cylinders. That theſe cylinders are formed by an extremely thin tunic, uniformly filled by a gelatinous tranſparent humour, which is inſoluble in water; each of theſe cylinders is covered by an external ſheath, which is compoſed of a great number of twiſting threads. Many tranſparent cylinders conſtitute a nerve which is ſcarcely viſible to the naked eye, and many of theſe form the nervous cords which are ſeen in animals.

The Abbè Fontana alſo ſubmitted to the microſcope the medullary and cortical parts of the brains of ſeveral animals. In theſe, however, the appearances were pretty ſimilar, and the ſubſtance of both appeared to be organic, vaſcular, tranſparent, and twiſting, like inteſtines.

The nerves proceed from the encephalon and ſpinal marrow. Ten pair are uſually enumerated as ariſing from the former, and thirty from the latter. I ſhall firſt deſcribe the origin and courſe of thoſe of the encephalon. Anatomiſts mention theſe in the order in which they preſent themſelves when the brain is lifted from the cranium; thoſe which come from the anterior part of the cerebrum are therefore placed before thoſe which ariſe lower down from the cerebellum and medulla oblongata.

The firſt pair of nerves is the olfactory, which proceed from the corpora ſtriata; they approach the cribriform plate of the os ethmoides, where they ſplit into a great number of filaments, which paſs through the per-

perforations of that bone. Afterwards being joined by a branch from the fifth pair, they are ſpread on the internal membrane of the noſe, and conſtitute the organ of ſmelling.

The ſecond pair of nerves is the optic, which are continued from the thalami nervorum opticorum, and are of a large ſize; they firſt make a large curve outwards, and then run obliquely inwards and forwards, till they unite at the fore part of the ſella turcica; they then divide, and each runs to its proper foramen in the ſphenoid bone. They are accompanied to the eye by the ocular artery, and are at length expanded into the tender and pulpy ſubſtance of the retina, which receives the impreſſions of light. The union of the optic nerves has been thought to explain ſome phenomena of viſion, as our ſeeing objects ſingle with two eyes, and their uniform motion. The union of the optic nerves generally appears ſo conſiderable, that ſome anatomiſts have thought that they decuſſated each other, and went to the eye on the oppoſite ſide of the head from that whence they aroſe. In many fiſhes the optic nerves evidently croſs each other, but this does not ſeem to be the caſe in man. They are inſerted into the eyes, not directly at their poſterior part, but rather towards that ſide which is placed next the noſe. We are unable to ſee with that part of the retina where the optic nerve enters.

The third pair called motores oculi ariſes from the crura cerebri, near the pons Varolii; they run along the ſide of the ſella turcica, and paſs out at the foramina lacera, after which each of them divides into branches; one of theſe, after forming a ganglion, is diſtributed to the globe of the eye; the others are ſent to the muſculus rectus of the palpebra, and to the attollens, adductor,

ductor, deprimens, and obliquus minor mufcles of the eye-ball.

The fourth pair of nerves called pathetici, are the fmalleft of all; they arife from near the tubercula quadrigemina; they pafs out at the foramina lacera, and are entirely fpent on the mufculi trochleares or fuperior oblique mufcles of the eye-balls.

The fifth pair is the largeft of thofe which proceed from the head; they rife from the crura cerebelli, where they join with thofe of the cerebrum, to form the tranfverfe protuberance or pons Varolii. In their progrefs they appear thicker at the fides of the fella turcica, where each forms a diftinct ganglion, from which proceed three branches, which pafs out of the cranium.

The firft branch of the fifth pair is the opthalmic; it paffes out of the foramen lacerum, and is in its paffage connected with the fixth pair; it afterwards communicates with the firft and third pairs, and is chiefly fpent on the orbit and the appendages of the eye. One branch paffes through the foramen fuperciliare of the os frontis, to be diftributed on the forehead.

The fecond branch of the fifth pair is chiefly fpent on the parts of the upper jaw, and is therefore called maxillaris fuperior; it is diftributed on the upper jaw bone and its teeth, on the fore part of the palate, the cheeks, upper lips, and noftrils. This branch communicates with the fixth pair of nerves, and with the portio dura of the feventh pair.

The third and moft confiderable branch of the fifth pair is the maxillaris inferior; part of this is loft in the tongue; another part goes to the teeth of the lower jaw, to each of which it fends a feparate twig;

it

it is partly alſo diſtributed on the muſcles of the lower jaw.

The ſixth pair of nerves is ſmall, and is chiefly diſtributed on the abductor muſcle of the eye; it ariſes from the fore part of the corpora pyramidalia, and in its progreſs towards the foramen lacerum paſſes through the receptacula at the ſides of the ſella turcica, where it is immerſed in blood, but for what purpoſe is unknown. In the paſſage of this nerve below the dura mater, it lies very contiguous to the carotid artery, and at this part a twig from it deſcends with the artery to form the beginning of the intercoſtal nerve.

The ſeventh pair comes out from the lateral part of the tranſverſe protuberance, and appears to be double, each being accompanied with a larger artery than moſt other nerves; it then enters the internal meatus auditorius, where it ſeparates into two diſtinct portions; one of theſe goes to the internal parts of the ear, and is there expended in producing a pulpy membrane reſembling the retina; this diviſion of the nerve is called the portio mollis; the other, the portio dura, communicates with the fifth pair, and piercing through the parotid gland is divided into numerous ramifications, which are ſpent on the upper part of the neck and ſide of the head.

The eighth pair of nerves, which from the length of its courſe and the variety of parts to which it is diſtributed is called par vagum, ariſes from the lateral baſis of the corpora olivaria in ſeparate fibres. The eighth pair is ſoon joined by the nervus acceſſorius, which is derived from the tenth pair of nerves, and from ſeveral of thoſe of the neck; thus united, they paſs out of the cranium through the ſame opening with the internal jugular vein; when they get out of the

the cranium the nervus acceſſorius leaves the eighth pair, and paſſing through the ſterno maſtoideus muſcle, is diſtributed on that and the trapezius. The eighth pair now diſperſes various branches to the tongue, larynx, and pharynx, which are united with branches of the fifth pair, with the portio dura of the ſeventh pair, with the recurrent nerve, with the great intercoſtal, and with the ninth pair and all the cervical nerves. Being ſeparated from theſe nerves it runs down on the external ſide of the carotid artery, and as it is about to enter the thorax, a conſiderable nerve called the recurrent is ſent off on each ſide. The right recurrent nerve takes a turn round the right ſubclavian artery, and the left round the aorta; and both of them running up again at the ſide of the œſophagus, to which they give branches, are ſpent on the parts of the larynx. We find from many inſtances that nerves court the neighbourhood of arteries, but what are the purpoſes of ſuch a diſtribution it is not eaſy to determine.

At the part from which the recurrent nerves ariſe, are alſo ſent off twigs which join with the branches of the intercoſtal, and which are diſtributed on the heart, where they form a plexus on the pericardium. The two trunks of the eighth pair now deſcend by the œſophagus to the ſtomach, where plexuſes are produced, whence the ſtomach is plentifully ſupplied with nerves, and ſome are ſent to the diaphragm, the liver, and the pancreas. From theſe are ſent branches, which contribute to form plexuſes on the ſpleen and kidneys. Near the cæliac artery the eighth pair alſo unites with the great ſemi-lunar ganglion, formed by the two intercoſtal nerves. I have been the more particular with regard ro the eighth pair of nerves, merely to give the reader an idea of the very com-

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plex manner in which the nerves are united to each other, and to evince the careful provifion which is made to fupply the moft important vifcera from a variety of fources.

The ninth pair or lingual, rifes from the inferior part of the corpora pyramidalia, and paffes out through the occipital bone. After they have arrived on the outfide of the cranium, they adhere firmly for fome way to the eighth and the intercoftal; then after fending a branch to communicate with the cervical nerves, they enter the tongue and are loft in its fubftance.

The tenth pair of the head is by fome anatomifts confidered as the firft of the vertebral. It rifes by feparate threads from the fide of the fpinal marrow, paffes out between the os occipitis and firft vertebra of the neck, and after having given branches to the great ganglion of the intercoftal, and fome of the cervical nerves, is loft in the adjoining mufcles.

It has been already mentioned that a branch of the fixth pair of nerves, joined by a twig from the fifth, accompanies the internal carotid artery through its bony channel, and paffing out of the cranium, both united conftitute the beginning of the great intercoftal or fympathetic nerve. As foon as the nerve has got without the cranium, it is connected a little way with the eighth and ninth pairs; feparating from thefe it forms a large ganglion, into which enter branches from the tenth of the head and from the firft and fecond pairs of the cervical nerves. Thence running down the neck with the carotid artery, and diftributing nerves to the adjoining mufcles, it forms another ganglion as it is about to enter the thorax, whence nerves are fent to the trachea and heart; thofe which go to the heart being united with nerves from the eighth pair. Below the fubclavian artery the fibres of the intercoftal

unite

unite to form a third ganglion. After this the trunk of the intercostal passes down by the spine, close to the transverse processes, through the cavity of the thorax. In this course all the dorsal nerves as they come from the spine contribute to its increase by the addition of twigs on each side. Descending still lower it receives similar accessions from the nerves which come out between the lumbar vertebræ and os sacrum. At the extremity of the os coccygis the intercostals of the opposite sides are turned inwards, and unite with each other. The intercostal is larger in the thorax than it is either above or below.

From the part whence the fifth, sixth, seventh, eighth and ninth dorsal nerves are sent to the intercostal, come out as many branches, which form an anterior trunk called the small intercostal nerve. This passes through the posterior part of the diaphragm to form with the great intercostal of the opposite side, and with the eighth pair, a large semi-lunar ganglion, situated between the cæliac and superior mesenteric arteries. From this ganglion, as from a center, nerves are sent to the liver, pancreas, spleen, duodenum, jejunum, ileum, and a large part of the colon.

Several fibres also passing downwards on the aorta, are joined by other nerves from the posterior trunk of the intercostal, and form plexuses, which supply the kidneys, glandulæ suprarenales, &c. They also form a plexus about the inferior mesenteric artery, which accompanies its branches to that part of the colon which lies at the left side of the abdomen, and to the rectum.

The first cervical pair of nerves comes out between the first and second cervical vertebræ; the second cervical pair between the second and third. These nerves communicate with each other, and with those nerves

of the head which paſs down to the neck. They are afterwards chiefly ſpent on the extenſors of the head, the levators of the ſcapulæ, and the neighbouring integuments.

The third cervical nerve paſſes from the ſpinal marrow, between the third and fourth vertebræ, and joining with the fourth cervical, forms the phrenic nerve, which paſſes down by the ſubclavian veſſels in its way to the diaphragm, on which it is expended. The other branches of the third pair are diſtributed to the muſcles of the neck and top of the ſhoulder. Hence it has been attempted to account for the pain at the top of the right ſhoulder in inflammations of the liver. The diaphragm is ſuppoſed to be affected either by its contact with the liver, or by the increaſed weight of that viſcus pulling it downwards; and the ſhoulder is thought to ſympathize with the diaphragm, becauſe it receives nerves from the ſame ſource. This explanation, however, is very unſatisfactory, ſince nothing is more common than for parts to be ſupplied by the ſame nerves without having any ſuch ſympathy.

The fourth cervical nerve, after having given off that branch which joins with the third to form the phrenic, paſſes to the axilla, where it forms a plexus with the fifth, ſixth, and ſeventh cervical nerves, and with the firſt of the dorſal. After giving ſeveral conſiderable nerves which are diſtributed on the muſcles of the thorax, they form ſeveral branches which paſs down on the arm, and ſupply the whole ſuperior extremity.

The dorſal nerves are twelve in number, and all contribute to the formation of the great intercoſtal. The firſt of the dorſal nerves differs from the reſt in contributing to the formation of the brachial nerves,

 and

and in forming a large ganglion with the intercoſtal nerve.

The dorſal nerves alſo give branches backwards to the ſtrong muſcles ſituated on the ſpine, and which ſerve to erect the body. Their principal trunks accompany the intercoſtal arteries in the groove at the bottom of each rib, and are diſtributed with them to the ſides and anterior parts of the thorax. The ſix lower dorſal nerves alſo give branches to the diaphragm and abdomen. The twelfth joins the firſt and ſecond of the lumbar, and beſtows nerves on the quadratus lumborum, pſoas, and iliacus internus.

The firſt and ſecond of the lumbar nerves ſend branches which join with others from the third and fourth, and form a large nerve which paſſes through the foramen thyroideum, and is ſpent on the muſcles and integuments at the inſide of the thigh; it is called the obturator or poſterior crural nerve. By branches from the four upper lumbar nerves is alſo formed the anterior crural nerve, which paſſes out of the abdomen under the ligament of Fallopius, and is diſtributed on the integuments and muſcles at the fore part of the thigh. A branch of this nerve alſo attends the vena ſaphena to the foot.

The fourth and fifth lumbar nerves contribute with the three ſuperior ſacral nerves to form the largeſt nerve of the body, the ſciatic. This nerve, after giving nerves to the muſcles about the hips, paſſes behind the tuberoſity of the iſchium, and then downwards, cloſe to the poſterior part of the os femoris. Diſtributing nerves through its whole progreſs it runs down the back part of the leg, and terminates in the ſole of the foot. The fourth, fifth, and ſixth anterior ſacral nerves are much ſmaller than the ſuperior, and are chiefly diſtributed on the bladder, rectum, and anus. Small

nerves

nerves paſs through the poſterior openings of the os ſacrum, which are diſtributed on the hips and neighbouring muſcles.

Nerves may more properly be ſaid to be connected with the brain than to be produced from it, ſince fœtuſes have been born with a brain not larger than a hazel nut, and yet with nerves of the uſual ſize.

The uſes of the nerves are very important, but are beſt diſcovered from obſerving the effect of their abſence. When a nerve is cut or tied, the part to which it belonged is inſtantly deprived of ſenſation, and the will has no longer any command over it. The nerves are therefore the inſtruments of ſenſation, and the organs by means of which the brain maintains a communication with the moſt diſtant parts of the body.

After having conſidered the ſtructure of the different parts of the human body, can we refrain from pauſing a few moments to contemplate ſo wonderful a fabric? But man is only a ſingle inſtance of the wiſdom of Providence; every part of the world contains animals, the ſtructure of which is not leſs complex than our own, and the conſtitutions of which are ſuited to the climates they inhabit. All of them are furniſhed with organs for their ſubſiſtence, their defence, and their enjoyment, and theſe organs are adapted to their ſeveral neceſſities, and have correſponding relations in the objects, as well animate as inanimate, which ſurround them. Not only the ſurface of the earth, however, but the atmoſphere, the ocean, the herbage, the ſoil, teem with the animal creation. How far this ſyſtem may extend we know not; but obſervation has hitherto continually enlarged our proſpects, without marking a ſingle limit; and it is not improbable, that the animal which dwells on the body of another, may itſelf be a

theatre of life, on which ſtill more minute animals take their ſport and paſtime.

From theſe views ſhall we turn to the heavenly bodies, and ſuppoſe that ſuch vaſt maſſes of matter are deſtitute of inhabitants? The planets as well as the earth receive the rays of the ſun, and ſome of them which are far removed from his light, are furniſhed with moons. Were theſe moons, which are only viſible by the teleſcope, deſigned for our amuſement, or for the uſe of beings placed ſufficiently near to profit by their influence? What ſhall we think of thoſe ſtill larger bodies, the ſtars, which multiply upon us without end, in proportion as we are furniſhed with more extenſive means of obſerving them. But the Deity has placed no bounds to our admiration; for he has made ſpace appear to the human mind neceſſarily infinite, and time, everlaſting.

The figure in the annexed plate (XIV.) repreſents the diſtribution of the nerves.

a, A part of the firſt branch of the fifth pair of nerves, called the ophthalmic branch, going out of the orbit, and winding upon the forehead.

b, The orbital branch of the ſecond branch of the fifth pair, going out at the foramen below the orbit, and diſtributing its branches on the lower part of the face below the eye.

c, A part of the maxillary branch of the third branch of the fifth pair of nerves, going out by a canal in the lower jaw-bone by the ſide of the chin and lower lip.

d, The trunk of the eighth pair of nerves, joined with the recurrent nerve.

e, The trunk of the eighth pair of nerves cut off.

f, The

f, The ſpinal recurrent nerve. *g*, A branch of it belonging to the cleidomaſtoideus and ſterno-maſtoideus muſcle.

h, The conjunction of the recurrent nerve with the third of the cervical nerves. Afterwards the recurrent winds backwards.

i, *i*, *i*, The left intercoſtal nerve.

k, The upper cervical ganglion of the intercoſtal nerve.

l, A branch of the ſecond cervical nerve, going to join the ganglion *k*.

m, A branch of the firſt cervical nerve, going to the ſame ganglion *k*.

n, *o*, Branches from the cervical nerves, going to the intercoſtal nerve.

p, The ganglion of the intercoſtal nerve in the upper part of the thorax.

q, *q*, &c. Branches, by which the intercoſtal nerve is conjoined with the ſpinal nerves; viz. by the ſeventh and eighth of the cervical, and all the dorſal and lumbar.

r, *s*, The extremity of the intercoſtal nerve, belonging to the firſt nerve *r*, and the ſecond *s* of the os ſacrum.

t, A conſiderable nerve, ariſing from the intercoſtal near the vertebræ of the back; here indeed it has ſix beginnings, according to thoſe branches by which the intercoſtal is joined with the fourth, fifth, ſixth, ſeventh, eighth, and ninth dorſal. Which nerve, here cut off, paſſes through the diaphragm into the abdomen, where it joins itſelf with the eighth pair of nerves of the brain, and with other branches of the intercoſtal nerve, &c.

u, A branch of the intercoſtal nerve,

w, *w*, &c. Branches by which the right intercoſtal nerve is joined with the ſpinal nerves.

x, *y*, Thoſe branches of the right intercoſtal, which *r*, *s*, repreſent of the left.

z, *z*, Branches.

A, A, Branches.

B, B, The firſt pair of cervical nerves.

C, C, Branches, by which the ſecond pair of cervical nerves is joined with the third.

D, D, The ſecond pair of cervical nerves.

E, E, Branches, by which the third pair of cervical nerves is joined with the fourth.

F, F, The third pair of cervical nerves.

G, G, The fourth pair of cervical nerves.

H I K, H I K L, The phrenic nerves, ariſing by two origins, the one H from the fourth cervical pair, and the other I from the fifth. K, K, Their trunks, the left of which, upon account of the point of the heart's being turned to the left ſide, is bended towards the left. L, The extremity of the right, branched out upon the diaphragm.

M, M, The fifth pair of cervical nerves.

N, N, The ſixth pair of cervical nerves.

O, O, The ſeventh pair of cervical nerves.

P, P, Branches of the firſt pair of dorſal nerves, going to join the eighth pair of cervicals.

Q, R, &c. The coſtal branches of the dorſal nerves, which run according to the length of the ribs. Q, Q, The firſt, R, R, the ſecond, S, S, the third, T, T, the fourth, U, U, the fifth, V, V, the ſixth, W, W, the ſeventh, X, X, the eighth, Y, Y, the ninth, Z, Z, the tenth, α, α, the eleventh, β, β, the twelfth.

δ, A branch of the ſecond coſtal nerve, which paſſes through

through the external intercoſtal muſcle, immediately under the origin of the ſerratus magnus, which proceeds from the ſecond rib; afterwards it bends itſelf backwards according to the directions of the origin of the ſerratus magnus, and then diſtributes itſelf upon the outſide of the latiſſimus dorſi under the ſkin.

ε, A ſimilar branch of the third coſtal nerve, paſſing through in the ſame manner, and diſtributed as the former.

ζ, A ſimilar branch of the fourth coſtal nerve, which when it has got under the ſkin, winds partly backwards, and partly forwards and downwards.

η, A ſimilar branch of the fifth coſtal nerve, which paſſes firſt through the external intercoſtal muſcle, then through the head of the external oblique, that part of it which riſes from the fifth rib, and afterwards runs along under the ſkin.

θ, ι, κ, Branches of the ſeventh θ, the eighth ι, and the ninth coſtal nerve κ, diſtributed to the internal part of the external oblique muſcle of the abdomen.

λ, A branch of the tenth coſtal nerve, which, after having paſſed through the external intercoſtal muſcle and the tranſverſe, runs forwards between the tranſverſe and internal oblique muſcles towards the rectus muſcle, and paſſes through it likewiſe by the aponeuroſes of the oblique muſcles to the parts below the ſkin.

μ, A branch of the eleventh coſtal nerve, which follows the ſame courſe with that of the tenth, λ.

ν, A branch of the tenth coſtal nerve, beſtowed upon the inſide of the internal oblique muſcle.

ξ, A branch of the eleventh coſtal nerve, beſtowed the ſame way as the laſt, ν.

 ο, π, Theſe

o, π, These appear to be branches of the twelfth costal nerve, running between the transverse and internal oblique muscles.

ρ, This is a branch of the first pair of lumbar nerves, running likewise between the transverse and internal oblique muscles.

σ, σ, Branches of the twelfth pair of costal nerves.

τ, τ, The first pair of lumbar nerves.

υ, A branch of the first pair of lumbar nerves.

ϕ, The second pair of lumbar nerves.

χ, The second of the lumbar nerves, joins with the third, and with the upper root of the nerve I.

ψ, A nerve, marked Φ, on the left side, arising here by a double origin, one from the first pair of lumbar nerves, and the other from the second.

ω, The third of the lumbar nerves.

Γ, The fourth of the lumbar nerves.

Δ, A branch, which is sent from the fourth pair of lumbar nerves to join the sciatic.

Θ, Θ, The fifth pair of lumbar nerves.

Λ, Λ, The first pair of nerves of the os sacrum.

Ξ, Ξ, The second pair of nerves of the os sacrum. That on the right side is joined by an intermediate branch with the third.

Π, Π, The third pair of nerves of the os sacrum.

Σ, Σ, The fourth pair of nerves of the os sacrum.

Φ, A nerve, whose origin is marked Ψ on the left side, emerging from the great psoas muscle, and going down along with it into the groin.

Ψ, A nerve, which arises by a double origin from the second lumbar nerve ϕ, where its roots are cut through.

Ω, A branch of the crural nerve, which is conjoined into one with the nerve, ψ.

I, I, A con-

1, 1, A confiderable nerve on each fide, which arifing by two roots, the one from the fecond and third, and the other from the fourth of the lumbar nerves, runs down firft under the great pfoas mufcle, then by the fide of the pelvis to the upper part of the foramen thyroideum, where it divides into two branches, the anterior, 2, and the pofterior, 3.

2, The anterior, goes out immediately above the obturator mufcle by a finus, in the upper part of the foramen thyroideum.

3, 3, 4, The pofterior, paffes through the fame finus, and, running immediately down between the two obturators, gives a branch to the external; it goes out then by that external branch, 4.

5, The fciatic nerve.

6, 6, The crural nerves.

7, 7, Branches of the crural nerves, going to the internal iliacs.

8, 8, The external branches of the crural nerves, which running down the thighs, give branches to the internal iliac mufcles, the mufculi recti of the leg, the vafti interni, the crurei, and the vafti externi.

9, 9, The internal branches of the crural nerves, which run down the thigh, and in their courfe give off branches to the vafti interni.

10, 10, The roots of the nerves.

11, 11, The roots of the nerves.

12, Here the internal branch of the right crural nerve, emerging between the mufcles gracilis and fartorius, is cut off.

13, The root of that branch.

14, The internal branch of the left crural nerve cut off.

15, 15, Branches

15, 15, Branches of the sciatic nerves. They produce the branches, 17, 17, 18, 19, 20, 21: of which 17, 17, belong to the long extensors of the toes; 18, to the peroneus longus; 19 is subcutaneous, and divides itself into two branches, which answer to the branches 20 and 21; 20, 21, are a variation of the branch 19, dividing itself sooner into 20, 21.

22, 22, The fifth, sixth, seventh, and eighth pair of cervical nerves.

23, A branch, which, arising from the above nerves in their course to the axilla, is distributed to the inside of the pectoral muscle.

24, A branch, which, arising in the same manner from the above nerves, is bestowed upon the inside of the serratus anticus.

25, 25, A branch, which, going off like the former from the above nerves, belongs to the muscle called latissimus dorsi.

26, A branch of the sixth pair of cervical nerves, bestowed upon the serratus magnus muscle, running down according to the direction of that muscle, and afterwards under the latissimus dorsi.

27, 28, 29, 30; 27, 28, 29, 30. The four large brachial nerves, in which those running on each side by the axillæ principally terminate. 27, 27, The first, which in a manner perforate the musculi coracobrachiales. 28, 28, The second, which run according to the length of the humerus as far as the bending of the arm, and thence by the fore-arm, down to the palm of the hand. 29, 29, The third, which run on the back part of the humeri.

30, 30, The fourth, which run down, according to the

the length of the humerus, to the poſterior part of the large condyle, and thence by the fore-arm to the palm of the hand.

31, A branch of the third brachial nerve 29.

32, The firſt of the brachial nerves 27, after it has run a little way under the coracobrachialis muſcle, makes its way through it, and afterwards runs under the ſhorter head of the biceps, giving branches to this, and the internal brachial muſcle; it is cut off, at 33.

34, A branch of the firſt of the brachial nerves, which it ſends off to join the ſecond. The ſame in the left arm.

35, 35, Here the ſecond trunks of the brachial nerves 28, 28, give branches to the pronatores and teretes, the radiales interni, the ſublimes, and palmares longi muſcles.

36, 36, Conſiderable branches of the ſecond brachial nerves, which ſend off branches to the profundi, and the long flexors of the thumbs; and afterwards 37, 37, get in between theſe muſcles, and run down to the pronatores quadrati muſcles.

37, This ſecond of the brachial nerves, paſſes through the ligament of the wriſt on the inſide; afterwards, 39 proceeds to the wriſt, where it divides itſelf into five branches, 40, 41, 42, 43, 44. Of which

40, The firſt, gives a branch to the third lumbrical muſcle, after which it divides itſelf into two; one branch running along the ſide of the ring finger next the middle finger, and the other along the ſide of the middle finger next to the ring finger.

41, The ſecond, gives a branch to the ſecond lumbrical, and afterwards divides likewiſe into two; one

one branch running along the ſide of the middle finger, next the fore finger, and the other along the ſide of the fore finger next the middle finger.

42, The third, gives a branch to the firſt lumbrical, and afterwards runs upon the ſide of the fore finger next the thumb.

43, The fourth, goes to the thumb, and, there dividing into two, runs upon each ſide of it.

44, The fifth, which is here cut off, gives a branch to the ſhort abductor of the thumb. And then it gets between the ſhort flexor and the muſculus opponens of the thumb, and belongs to the opponens.

45, 45, Continuations of the brachial nerves. The third pair of brachials 29, 29, after having run backwards by the ſhoulder-bones from the axillæ, and then between the external brachial muſcles on the one ſide, and the long and ſhort heads of the bicipites on the other, and afterwards between the internal brachials and long ſupinators, emerge here 45, 45, between theſe laſt-mentioned muſcles, and thence proceed to the inſide of the fore-arm, where having given off branches to the long ſupinators and external radial muſcles, they paſs through the ſhort ſupinators 46, 46.

47, 47, Nerves cut off.

48, 48, Branches of the fourth brachial nerve, 30, going to the external brachial muſcle 49, 49, to the internal ulnar, 50, to the profundus.

51, A branch of the ſame, which paſſes under the internal ulnar to the back part of the extremity of the fore-arm, and makes a ſubcutaneous nerve.

After

After giving off this branch, the fourth brachial nerve runs before the ligament of the wriſt inwards, towards the palm of the hand, where it divides into the branches 52, 53, 54. Of which

52, The firſt remarkable one, ſpreading itſelf in the wriſt under the tendons of the profundus and the lumbricales muſcles, its branches are diſtributed principally to theſe, viz. the abductor of the little finger, the adductor of the fourth metacarpal bone, the interoſſeous muſcles, the adductor of the thumb, the ſhort flexor of the thumb, and the abductor of the fore finger.

53, The ſecond, after it has given off the ſubcutaneous branch which is here cut away, and another to the abductor of the little finger, runs along the back part of the little finger.

54, The third, dividing into two at the roots of the ring finger and little finger; one branch runs along the ſide of the little finger next the ring finger, and the other along the ſide of the ring finger next the little finger.

Chap. XXIX.

CIRCULATION OF THE BLOOD.

Structure of the Heart, and Circulation in cold-blooded Animals.—Circulation in the warm-blooded Animals.—Course of the Blood through the Lungs.—Through the rest of the Body.—Ramifications of Arteries.—Valvular Structure of Veins.—Different from the Structure of Lymphatics.

THE ſtructure and uſes of the organs concerned in the circulation of the blood have been already conſidered, and it was farther remarked that the heart of man is of a duplex conſtruction, in other words, that it has *two* auricles and *two* ventricles. With a view to perſpicuity, before we proceed to the circulation in the human body, it will be neceſſary to mention the ſtructure of the heart in certain animals in which it is more ſimple.

In frogs, ſerpents, and other cold-blooded animals, the heart conſiſts of only two cavities, an auricle and a ventricle; from the auricle the blood paſſes into the ventricle, from the ventricle it is driven into the arteries, from the arteries it is received into the veins, and by the veins is again brought back to the auricle.

This being well underſtood, it cannot be difficult to comprehend the courſe of the circulation in man, and the warm-blooded animals, in which the only difference is, that the heart being double, or conſiſting of four cavities, the blood performs two circles inſtead of one. From the anterior auricle the blood paſſes into the anterior ventricle; from the anterior ventricle it is conducted by the pulmonary artery to the

the lungs, and from the lungs, the pulmonary veins bring it back to the pofterior auricle; from the pofterior auricle it paffes into the pofterior ventricle; from the pofterior ventricle it is carried to every part of the body, by means of the aorta and its branches, and thence is again brought back by the venæ cavæ to the anterior auricle, whence it proceeded. In this manner, throughout life, the blood is conftantly performing two circles; a leffer between the heart and the lungs, and a larger between the heart and the reft of the body.

The two auricles and ventricles are of equal capacity, and correfpond in their contractions. From thefe circumftances it is evident, that the fame quantity of blood paffes through the lungs in a given time, as through all the reft of the body, and, confequently, that the circulation muft be much more rapid in the lungs than in other parts. It is fuppofed that about two ounces of blood are thrown from each ventricle of the heart at every contraction.

The heart, however, though the moft remarkable, is not the only organ of circulation; fince every veffel through which the blood paffes affifts, by its contractile powers, to propel its contents. The fudden contractions of the heart, by which the blood is thrown into the arteries, occafion their pulfation, which is moft violent in the large trunks, gradually becomes lefs remarkable as they ramify and recede from the heart, and is not at all perceptible in the veins, which receive their blood from the arteries. The contraction of the ventricles, by which the blood is propelled from the heart, is called the fyftole; the dilatation, by which the blood is received into them, the diaftole.

The ftructure of the heart in the tortoife and fome other

other amphibious animals is intermediate between that of cold-blooded animals and warm-blooded.

The heart has two diſtinct auricles, without any communication: and under theſe, there is the appearance of two ventricles ſimilar in ſhape to thoſe of the latter claſs: but they may be conſidered as one cavity; for the ventricle ſends out not only the pulmonary artery, but likewiſe the aorta; for there is a paſſage in the ſeptum, by which the ventricles communicate freely, and the blood paſſes from the left into the right one. From the aorta the blood returns into the right auricle, while that from the pulmonary artery returns to the left auricle, from which it is ſent to the left ventricle, &c. ſo that only a part of the blood is ſent to the lungs, the reſt going immediately into the aorta; hence the animal is not under the neceſſity of breathing ſo often as otherwiſe it would be.

The ends of the arteries are the beginnings of the veins, which uniting, as the arteries divided, at length form large trunks, which generally correſpond with the trunks of the arteries, from which, by the medium of ſmaller branches, they received their contents.

But though all arteries terminate in veins, yet the minuteneſs of their ramifications, before this takes place, is various; while ſome tranſmit the red globules, others exclude them, and tranſmit nothing but ſerum.

A circumſtance contributing greatly to the progreſs of the blood in the veins is their valvular ſtructure, fitting them for deriving aſſiſtance from preſſure; and we find accordingly in the limbs, and wherever elſe any advantage could be obtained from this circumſtance, that the veins are furniſhed with valves, while in the cavities of the body, where they are not ſo much preſſed by the action of muſcles, this part of their ſtructure is wanting.

The motion of the fluids of the valvular lymphatic ſyſtem is quite diſtinct from the circulation of the blood. Theſe veſſels begin by open mouths, which perform the office of abſorption, and their contents are not derived, like thoſe of the red veins, from the extremities of arteries; their fluids are therefore propelled, without any aid from the heart, by their own contractile powers.

The moſt remarkable functions, to which the circulation of the blood is ſubſervient, are ſecretion, the nouriſhment of the body, and certain changes which the blood undergoes in its paſſage through the lungs; of theſe it will be proper to treat in the chapters immediately ſucceeding.

Chap. XXX.

SECRETION, EXCRETION, ABSORPTION, AND NOURISHMENT.

General Effects of Secretion.—The Glands.—Excretion.—Secretion of Bile.—How this Function is performed in Fishes.—Absorption.—Lymphatic Glands.—Nourishment or Reparation of the Body.—Bones become more solid in old Age.

THERE is no function of the body which is more calculated to excite our astonishment and admiration, than that of secretion. By secretion we see one fluid, the blood, modified more variously and more exquisitely than the human mind can easily conceive, or ever hope to explain; in one part, secreted fluids, varying in different races of animals according to their food, are endued with a power of dissolving the aliment, and fitting it for the nourishment of the body; in other parts, secretion furnishes fluids for lubricating the organs concerned in the various functions of the animal machine. In some animals the most powerful odours, in many the most deadly poisons, and in all, that wonderful fluid by which their race is perpetuated, are the products of secretion.

So far are we from discovering the nature of secretion, and the causes of the different properties of the fluids which are secreted, that we in reality know little more of this function, than the general outlines of the structure of the parts concerned in it. We see a gland, with an artery, vein, and excretory duct connected to it, but whether the secreted fluid is formed by exudation through the coats of the minute arteries dis-

tributed in the gland, or whether it is poured out from the open extremities of arteries into ſmall receptacles, and is thence received into the excretory duct, or in what other mode the change wrought on the blood conveyed to the gland is effected, we are entirely ignorant. So different, however, are the properties of ſecreted fluids from thoſe of the blood, that it is probable ſomething more happens than a mere ſeparation of principles, which previouſly exiſted in that fluid.

By ſome phyſiologiſts it has been imagined, that ſecretion may be explained on the ſimple ſuppoſition of a difference of diameter in the veſſels from which the ſecreted fluids are poured out. On this idea it has been advanced, that the thinneſt fluids are formed by the arteries of the ſmalleſt diameter, and the more denſe by arteries of a larger ſize; but it is evident, that though the ſmaller arteries would exclude the larger particles, ſtill the larger arteries would ſuffer the ſmaller particles to paſs through them, and thus the ſecretion be in ſome meaſure confounded.

Excretion, like ſecretion, is performed in general by arteries. The term ſecretion is applied to the formation of thoſe fluids which are ſubſervient to ſome purpoſe in the animal machine; that of excretion to the formation of ſuch as are apparently of no particular uſe, and which ſeem to be ſeparated for no other end than to be diſcharged from the body. It is difficult, however, to apply theſe diſtinctions to particular caſes, ſince there is hardly any one of theſe fluids, the production of which is not in ſome way uſeful, and but very few which may not be conſidered as in ſome degree excrementitious.

Both ſecretion and excretion are in many parts of the body performed by the minute ramifications of ar-

teries opening on the ſurface of membranes, without the intervention of glands. Fluids, which are deſigned for the lubrication of paſſages, are very generally diſcharged into ſmall bags or follicles, whence they are expreſſed, when their preſence is moſt neceſſary.

Few of the ſecreted fluids are diſcharged from the body exactly in the ſtate in which they were firſt prepared, but gradually become more viſcid or acrid; ſince, while they remain in the receptacles deſtined for their preſervation, their more watery parts are continually taken away by the action of the abſorbents.

We have hitherto conſidered ſecretion to be on every occaſion the work of arteries, but it is now neceſſary to take notice of a remarkable exception to this rule, and to inform the reader, that the moſt copious ſecretion in the body is performed by veins. The blood, which is carried by the arteries to the body at large, is generally returned by the readieſt paſſages to the heart; but it is ordered otherwiſe with reſpect to that which is ſent to the bowels.

The blood from the abdominal viſcera is received by a large vein, furniſhed with remarkably denſe coats, and called, from entering the liver as through a gate, the vena portarum; this vein is diſtributed through the ſubſtance of the liver, in the ſame manner as arteries are diſtributed through other glands.

The liver, however, is furniſhed with an artery which may poſſibly have ſome influence in the preparation of the bile. The ramifications of this artery inoſculate with thoſe of the vena portarum, and the blood from both is returned together to the heart, by veins which empty themſelves into the vena cava.

A fact

A fact so contradictory to the analogy of the other secretions cannot fail to excite our wonder and curiosity. Our curiosity we cannot hope to gratify, since the present state of our knowledge, with respect to the nature of secretion, gives us little room to expect a discovery of the advantages which are derived from this or any other peculiarity in our frame; but our wonder will be lessened by considering, that the same peculiarity takes place in certain animals, under circumstances still more remarkable. In fishes, a single artery arises from the ventricle of the heart, which is entirely distributed on the gills; from the gills the blood is gradually collected into a large vessel, corresponding to the aorta in man, and distributing the blood to every part of the body. From the bowels, however, the vessels still again unite, and form a large trunk, which, entering the liver, performs the secretion of the bile, in the third circle of the blood, since it passed through the heart; whereas in man the blood, in passing through the liver, is only in its second circle or course.

Absorption, as was before remarked, is performed by a system of vessels quite distinct from those concerned in the circulation of the blood. Their appearance, structure, and course through the body, have been already described. The uses of the absorbents in the animal œconomy are of the most important nature. By the absorbents all the nourishment of the body is conveyed from the intestines towards the heart; and by the absorbents those particles, which have become useless in any of the organs, are taken up, conveyed into the mass of circulating fluids, and ultimately discharged from the body. The bones themselves afford evidence of the action of the absorbents, as their component particles are continually

changing throughout life, and as all the bones loſe conſiderably of their weight in extreme old age.

At the ſame time, however, that their actual weight is leſſened, their ſpecific gravity is increaſed; for the bones of old people are thinner and more compact in their ſides, and have larger cavities. By chemical analyſis, the proportion of earth is found to be increaſed in the progreſs of life.

The abſorbents are particularly numerous in glands, and very probably have their influence in producing the phenomena of ſecretion. The fluids, which are ſecreted, for lubricating the joints and muſcles, and for moiſtening the ſeveral cavities of the body, are continually renovated by the abſorbents, which take up what is already effuſed, while more is ſupplied by the arteries.

The uſes of the glands connected with the lymphatic veſſels are not well underſtood, but from their being univerſal, and from our not being able to find a ſingle lymphatic veſſel, which does not, in its progreſs towards the heart, paſs through ſome of them, it may be concluded that their uſes are very important. One of the purpoſes, however, which they ſerve, is, probably, to impede any thing injurious, which may be taken up by the abſorbents, from entering the maſs of blood; and in this way the minute ramifications, into which the lymphatics are divided in their paſſage through theſe glands, may perform the office of a filter. There are ſeveral arguments which might lead us to believe, that the lymphatic glands belonging to the lacteals have ſome ſhare in digeſtion, or in fitting the chyle for entering the maſs of circulating fluids; but their influence in this reſpect is not proved, nor does it ſeem eaſy to aſcertain it. Several hypotheſes have been formed by ingenious men, with a view

view to explain the mode in which the absorbents act in taking in their contents; but as they are but hypotheses, I shall pass them over in silence.

As the absorbents are continually taking away the substance of the body, it was necessary that there should be organs, which, by furnishing fresh particles, might counterbalance their effects; and these organs are the arteries. It has been already observed that the arteries, for an important purpose, convey the blood to every part of the system; by means of the blood, however, the arteries not only produce the secretions, but furnish matter to every exhausted organ of the body; and from one fluid, restore the lost particles of the bones, the muscles, and the nerves, or whatever other solids stand in need of repair.

This office, however, of the arteries, pre-supposes that there must be a source, from which they are themselves supplied with the substance they furnish to the other organs; and this leads to the consideration of the important function of digestion.

Chap. XXXI.

DIGESTION.

Senſations of Hunger and Thirſt.—Progreſs of the Food to the Stomach.—Digeſtion, how performed by Men and Quadrupeds.—By Birds.—The Gizzard of Fowls, and its Uſes.—Birds of Prey.—Reaumur's Experiments on the Digeſtion of Fowls.—Motion of the Stomach and Gizzard.—Balls of Hair found in the Stomachs of Quadrupeds.—Gaſtric Fluid.—Stomach itſelf partly diſſolved by its Action after Death.—Fermentation only takes place in diſeaſed Stomachs.—What Subſtances are digeſtible, and the contrary.—Powers of Digeſtion in different Animals.—Carnivorous.—Granivorous.—Gramenivorous.—Sleeping Animals.—Accommodating Power of the Stomach.

ANIMALS are powerfully admoniſhed to repair the waſte of their bodies by an averſion from the ſenſations of hunger and thirſt, and a deſire of that pleaſure which attends the gratification of theſe appetites. Solid food, being taken into the mouth, is maſticated by the teeth, and mixed with ſaliva and mucus, which, by the preſſure and action of the parts, are very copiouſly exuded. Thus ſoftened and lubricated, the food is conveyed to the root of the tongue, and the lower jaw being now fixed by the ſhutting of the mouth, we are prepared to act with the muſcles which paſs the bone of the lower jaw to that which ſupports the tongue, called the os hyoides. A convulſive action of theſe muſcles ſuddenly draws forwards the os hyoides, the root of the tongue, and the larynx; the pharynx is enlarged, the food is forced into the gullet, and in its paſſage preſſes down the epiglottis, ſo as to prevent any thing from getting into

into the windpipe. The parts before thrown into action are now relaxed; the food is received by the gullet, and is regularly but rapidly conveyed to the stomach. Fluids are conveyed to the stomach in the same manner as solids. So perfect and exact is the action of the gullet in propelling its contents, that even air cannot elude its grasp, which is proved by our having the power of swallowing air, by taking a mouthful of it, and using the same efforts which we employ in swallowing our food.

After the food has reached the stomach, it is still further softened, and at length reduced to a pulpy consistence, by means which we shall presently examine. It now passes through the pylorus, or right orifice of the stomach, into the duodenum, where it is retained for some time, and attenuated by the admixture of the bile from the liver, and the pancreatic juice from the pancreas. From the duodenum it passes into the jejunum and ileum, in which it is moved backwards and forwards by the muscular contraction of their coats, called their peristaltic motion. As it proceeds, its more fluid parts are continually taken up by the lacteals, and it consequently gradually becomes of a thicker consistence. From the small intestines it passes through the valve of the colon into the large. Here it probably undergoes still further changes, and more of its fluid parts are absorbed by the lacteals. It is at length received by the end of the intestinal tube, called the rectum, and being of no further use, is discharged from the body.

The chyle, which is the product of the digested aliment, after it enters the lymphatics, is conveyed to the heart, and mixed with the mass of blood. Let us now examine the instruments, which nature employs in so wonderful a process, as that of fitting dead mat-

ter,

ter for receiving active properties, and being endued with life.

'A great many ſubſtances may enter the lacteals along with the chyle, even ſolids reduced to fine powder. When indigo has been thrown into the inteſtine of a ſheep, I have ſeen the chyle rendered quite blue: now indigo is not ſoluble in water, but is a ſolid reduced into a very fine powder. So muſk gets into the chyle, giving it a ſtrong ſmell, and a great variety of other ſubſtances of various colours, various taſtes, and various ſmells, each of them giving colour, or taſte, or ſmell, to the chyle. Nevertheleſs the lacteals ſeem to poſſeſs ſome power of rejection, ſince green vitriol, either exhibited along with the food, or thrown into the inteſtine after the animal has been opened, while chyle was forming and abſorbing, gives no colour on infuſion of gall being applied to the chyle; nor if galls are thrown into the ſtomach along with the food, or if an infuſion of them is in like manner thrown into the inteſtine, when an animal is opened, during the time that the chyle is flowing into the lacteals, do they give any colour upon a ſolution of green vitriol being applied to the chyle *.'

Dr. Fordyce mentions ſeveral inſtances of the ſtrong aſſimilating powers of the ſtomachs of certain animals; ſuch as fiſh thriving, increaſing in ſize, and excluding fæculent matter when confined in ſpring water, without any perceptible ſource of nouriſhment, and even when a communication with the air was cut off. He alſo remarks, that not only farinaceous and other bland ſubſtances are found to be attacked by inſects, but alſo jalap, ſcammony, hemlock, and the moſt deadly vegetable poiſons. Even cantharides are greedily de-

* Fordyce on Digeſtion, p. 122.

voured

voured by two ſpecies of inſects, not part of them picked out from other parts, but the whole entirely, without leaving a veſtige of any the leaſt part of the cantharis undevoured. Dr. Fordyce has procured theſe inſects from cheſts of cantharides imported from Sicily, and which had lived upon the cantharis for ſeveral months. After being waſhed with water ſlightly, theſe inſects have juices perfectly bland, ſo that if they are bruiſed and applied to any the moſt tender and ſenſible ſurface of the human body, they produce no inflammation, nor is there any appearance of their poſſeſſing any matter having a ſtimulating quality.

There are two different proceſſes, which in general ſeem eſſential to digeſtion; viz. trituration and the action of a certain fluid or menſtruum. All quadrupeds are furniſhed with teeth, by which they in ſome meaſure deſtroy the texture of their food before it paſſes into the ſtomach. The inſtrument of trituration in granivorous fowls, and which anſwers the purpoſes of the teeth of quadrupeds, is the gizzard, through which all their food paſſes, before it enters the organ, which may properly be denominated their ſtomach. Among fowls, however, there are ſome which have a ſtomach purely membranous, as the eagle, the hawk, and birds of prey in general. Theſe have neither gizzard nor teeth, but they are furniſhed with a ſharp and crooked beak, which, by tearing their food to pieces, ſerves in ſome meaſure to prepare it for the action of the other inſtrument of digeſtion, a fluid endued with peculiar qualities, and which, as far as our obſervations extend, ſeems to be in common to all animals.

The gizzard is an organ compoſed of very thick and ſtrong muſcles; it is lined internally with a ſubſtance ſo thick and callous as not to be hurt by grinding

ing down glaſs, and which is always found to contain ſmall ſtones of the hardeſt materials the bird can procure. By the help of theſe ſtones, and by means of the hard internal coat of the gizzard, and the force of its muſcular coat, the food is effectually ground down, and fitted for entering the inteſtines.

'Spalanzani, and others, have denied (ſays Dr. Fordyce) that they were of this uſe, and have affirmed that the ſtones were picked up by mere accident, the animals miſtaking them for ſeeds. But I have examined this particularly in experiments I made in hatching eggs with artificial heat; I have hatched vaſt numbers, and frequently have given the chickens ſmall ſeeds whole, taking care that they ſhould have no ſtones. In this caſe the ſeed was hardly digeſted, and many of the chickens died. With the ſame treatment in every reſpect, others who had their ſeeds ground, or have been allowed to pick up ſtones, have none of them been loſt. With tolerable care, when common chickens are once hatched by artificial heat, they are eaſily brought up without a hen, as by inſtinct they will keep in that part of the furnace where there is the proper degree of heat, and the proper expoſure to air. Inſtinct alſo teaches them what ſubſtances they ſhould chooſe for food, and what quantity of ſtones it is neceſſary to intermix with it. For if a very large quantity of ſmall ſtones is mixed with a ſmall proportion of grain, they will pick out the grain, ſo that the proportion of ſtones which they ſwallow ſhall be very little, if at all greater than when only a few were intermixed. In thoſe I examined the proportion of ſtones were not at all greater when there was a large quantity of them mixed with the grain, than when there was a ſmall proportion; and I have often obſerved them chooſing one piece of ſtone, and

rejecting

rejecting another. Birds have alſo an evident inſtinct even to diſtinguiſh one kind of earth from another, as may eaſily be ſeen in Canary birds; the hen, at the time of her laying her eggs, requires a quantity of calcareous earth, otherwiſe ſhe is frequently killed by the eggs not paſſing forward properly, as I have in many inſtances obſerved; to one ſet of hens a piece of old mortar was given, which they broke down and ſwallowed, certainly not miſtaking it for Canary ſeed, or any kind of food, but diſtinguiſhing it from a piece of brick, which they did not either break down or ſwallow; another ſet at the ſame time were kept without any calcareous earth; many of theſe died, while the others, although otherwiſe exactly in the ſame circumſtances, were none of them loſt. It appears therefore that birds have a neceſſity for ſtones being ſwallowed for digeſtion, and earths for other purpoſes, and that they have an inſtinct which diſpoſes them to chooſe the proper quantity and quality required. Moreover, as Mr. Hunter obſerves, the noiſe of the grinding may be heard, and therefore there can be no doubt that this ſtomach is made to contain ſtones for the ſame purpoſes for which teeth are employed *.'

The lobſter is furniſhed, for the comminution of its food, with an apparatus which is ſituated at the pylorus. It conſiſts of two bony ſurfaces, formed into ridges, which are applied to each other like thoſe of the molares. They are alſo covered, like our teeth, with enamel, and furniſhed with muſcles, by which the action of grinding is performed.

In order to diſcover the power of the gizzard, Reaumur gave to a turkey ſmall tubes of glaſs, five lines in length and four in diameter; theſe were broken in the gizzard in twenty-four hours. In the place of glaſs tubes he ſubſtituted tubes of tinned

* Fordyce on Digeſtion, p. 24, &c.

iron,

iron, ſeven lines in length and two in diameter, cloſed with ſolder at each end. Some of theſe were indented by the action of the gizzard, and others cruſhed quite flat. Similar tubes, placed between the teeth of a vice, required a force of four hundred and thirty-ſix pounds and a half to produce the ſame effects.

Incloſing in tin tubes, properly perforated, ſome grains of barley, ſome unboiled, ſome boiled, and others peeled, and letting them remain a day or two in the ſtomach, he found them only a little ſwelled. The ſame experiment being tried with meal, the ſame conſequences were obſerved, as it did not become in the ſmalleſt degree putrid. From theſe experiments Reaumur concluded, that digeſtion, in birds provided with a gizzard, was chiefly performed by means of trituration.

Such are the powers of the gizzard; but thoſe of the membranous ſtomach, though of a very different nature, are not leſs aſtoniſhing. It is well known that birds of prey, which ſwallow every part of the animal they devour without much diſtinction, have the power of throwing up ſuch parts of their food as they cannot digeſt. Taking advantage of this circumſtance, the ſame naturaliſt gave tubes, ſimilar to thoſe above mentioned, and filled with fleſh, to a buzzard hawk; in twenty-four hours the tubes being thrown up, the meat which they contained was reduced to an oily pulp, and with no appearance of putridity. At the end of forty-eight hours, the decompoſition was ſtill more perfect, the pulp was more attenuated and blanched, and that conſtantly without any ſmell. The tubes being filled with the bones of young pigeons, inſtead of butcher's meat, theſe were converted into a jelly in twenty-four hours. Beef bones, very hard, and deprived both of fleſh and marrow, out of forty grains,

grains loft eight in twenty-four hours, and in three days were totally diffolved. Grain and fruit expofed to the fame procefs, were very little if at all affected. Digeftion, therefore, in birds of prey is performed by a fluid, which acts only upon animal matter. This fluid is very abundant in the ftomachs of thefe animals. Small pieces of fponge, of thirteen grains, fhut up in the tubes, weighed three grains more when thrown up.

Notwithftanding thefe effects of the digeftive organs, the motions of the ftomach and the gizzard are fcarcely perceptible. There is reafon, however, to believe, that the little motion they have is very regular. On examining the furface of the balls of hair which are found in the ftomachs of animals which lick their coats, the hairs in each hemifphere feem to arife from a center, and to have the fame direction, which is circular, and correfponding with what would appear to be the axis of motion. This regularity in the direction of the hair could not be produced if there was not a regularity in the motion of the ftomach. The fame is proved in fome birds, as the cuckow, which fometimes feeds on hairy caterpillars.

The principal inftrument of digeftion in moft animals, is however now generally fuppofed to be the gaftric juice; a fluid which diftils from certain glands, fituated in the coats of the ftomach, and mixes with the food as foon as it is received into that organ.

The Abbé Spalanzani, in order to obtain a fight of the gaftric juice, introduced tubes, containing bits of fponge into the ftomach of a crow. In four hours the tubes were vomited up, and the fponges, being preffed, yielded thirty-feven grains of gaftric liquor, which was frothy, of a turbid yellow colour, had a tafte intermediate between bitter and falt, and being

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set to stand in a watch glass, deposited in a few hours a copious sediment. As the sediment might be attributed to the food suspended in the gastric juice, the experiment was repeated on a crow, the stomach of which was empty. The fluid obtained in this case was of a transparent yellow colour, deposited very little sediment, but the taste was the same. The gastric juice did not burn when thrown on hot coals, and paper moistened with it would not burn till the fluid was evaporated.

The motion of the stomach also assists in mixing and intimately blending this fluid with the proper parts of the aliment, so as to enable its solvent powers more completely to act upon it. The sensible qualities of this fluid are, however, not such as to lead us to attribute to it any such power; and I do not know that it has been completely analized by any chemical process, at least by any which enables us to explain its solvent property. A French * author, indeed, observing the power which inflammable air has in dissolving the texture of animal matter, has intimated an opinion, that a portion of the oily matter which is taken in with the food, may be modified by the stomach into inflammable air, and may perform this part of the process of digestion.

Digestion differs from all other processes, and can be compared neither to putrefaction nor chemical solution. A remarkable circumstance also with regard to digestion is, that by it both animal and vegetable matter is converted into the same substance.

Dr. Fordyce fed a dog with farinaceous matter, and another with muscle, and opening them both (in which he does not appear to have been justifiable)

* M. Sage.

during

during the time that the chyle was flowing through the lacteals, he collected from each as much chyle as he was able. On examination they were found so similar, that the difference could not be distinguished by any experiment which he could contrive. The chyle of a cat living on flesh, according to the same gentleman, cannot be distinguished from that of an ox or sheep.

Live or fresh vegetables, when taken into the stomach, are first killed, by which a flabbiness of texture is produced, as if they had been boiled, and then they begin to be acted on by the gastric juice. This fluid, indeed, seems to have no power to act on living matter, since worms remain uninjured in the stomach. Digestion, however, as far as relates to the dissolution of aliment, may be carried on out of the body by means of the gastric juice, and the application of heat equal to that of the human body. This process is continued for some time after death, and the stomach, no longer protected by the living principle, is itself partially dissolved by the gastric juice.

In the stomachs of large fish are commonly found small fishes, still retaining their natural form; but when touched, they melt down into a jelly. From this circumstance, and from the great quantity of fluids poured into their stomachs, we may conclude, that digestion is solely effected in them by the dissolving power of a menstruum, without the aid of trituration.

Neither animal nor vegetable substances can undergo their spontaneous changes, while digestion is going on in them. The gastric juice even has a power of recovering meat already putrid; for let putrid meat be given to a dog, and the contents of his stomach will be found sweet, and free from all putrefaction,

if he is killed a ſhort time after. Bread, which has remained in the ſtomach of a dog for eight hours, is ſo much changed, that it will not run into the vinous fermentation, but when taken out and kept in a warm place becomes putrid. Its putrefaction, however, is not ſo quick as that of a ſolution of meat which has been in the ſtomach for ſome time. The effects are ſimilar when milk and bread are the food.

When the digeſtive power, however, is not perfect, then the vinous and acetous fermentation will take place in vegetable matters, and the putrefactive in the ſtomachs of animals which live wholly on fleſh. The gaſtric juice apparently preſerves vegetables from running into fermentation, and animal ſubſtances from putrefaction, not from an antiſeptic quality in that fluid, but from a power of making them go through another proceſs. In moſt ſtomachs there is an acid, even though the animal has lived entirely upon meat for many weeks; this, however, is not always the caſe. The acid ſometimes prevails ſo much as to become a diſeaſe.

The ſtomachs of many animals have a power of coagulating milk; this is continually ſeen by infants throwing up their milk in a coagulated ſtate, and the ſame thing may be obſerved by feeding a dog with milk, and killing him half an hour afterwards. The ſtomach of the calf, and perhaps that of other animals, preſerves this power after death, and is kept dried, for the purpoſe of making cheeſe. Indeed milk, raw egg, and ſeveral other ſubſtances, require to be coagulated, before they can be digeſted.

If we throw milk into a portion of the jejunum, that milk will be abſorbed by the lacteals; but if we throw milk into the ſtomach of the ſame animal, the milk will not be abſorbed by the lymphatics; there-

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fore an argument might be brought, that the absorbents of the stomach would refuse what the absorbents of the jejunum would readily take up. But it must be considered thar the milk is instantly coagulated in the stomach, and not in the jejunum, which coagulation will perfectly prevent it from being absorbed; but all those substances which are not changed by the coagulating juice of the stomach will be, and are equally taken up by the lymphatics in the stomach and lacteals. There is, therefore, a conversion of the food in the stomach into a new substance, whose properties are at present unknown, which new substance is the only one which can be converted into chyle in the duodenum and jejunum, exactly as we may form farinaceous matter, mucilage, and native vegetable acid into wine; but before they can possibly be converted into wine, they must first be formed into sugar. So in a similar manner farinaceous matter, gum, and white of egg, are all capable of forming chyle; but before they are formed into chyle, they must be converted into a matter certainly not sugar, but a matter of a particular species in the stomach, and by the operation of the stomach, this particular species of matter is afterwards converted into chyle in the duodenum and jejunum.

Dr. Young, of Edinburgh, found that an infusion of the inner coat of the stomach, which had been previously washed with water, and then with dilute solution of mild fixed vegetable alkali, so that it was not possible that any acid could have remained in it, coagulated milk very readily. He found also that it had the power of coagulating serum, and other animal mucilages. The coagulating power of this substance is very great. Dr. Fordyce mentions that six or seven

grains of the inner coat of the ſtomach infuſed in water, gave a liquor which coagulated more than a hundred ounces of milk.

All fermentation is quite foreign to perfect digeſtion, and when it does take place, is always proportioned to the diſorder of the ſtomach, ſince very little if any wind or flatulency is generated in the ſtomachs of thoſe, whoſe digeſtion is moſt quick and eaſy. It is not uncommon, however, for milk, vegetables, wine, and whatever has ſugar in its compoſition, to become ſooner ſour in ſome ſtomachs than if left to undergo a ſpontaneous change out of the body; and even ſpirits, in certain ſtomachs, almoſt immediately degenerate into a very ſtrong acid. All oily ſubſtances, particularly butter, become rancid very ſoon after being taken into the ſtomach, and this rancidity is the firſt proceſs in the fermentation of oil. Animal food does not ſo readily ferment in diſeaſed ſtomachs, when combined with vegetables, as when it is not. Fleſh meat appears to undergo no change preparatory to digeſtion, but ſeems at once to ſubmit to the action of the gaſtric juice. It appears firſt to loſe its texture, then becomes of a cineritious colour, next gelatinous, and laſtly, is converted into chyle.

In order to aſcertain whether the production of any degree of acidity is eſſential to digeſtion, Dr. Fordyce made ſeveral experiments, from which he concludes, that in perfect digeſtion no acidity whatever is produced.

If the gaſtric juice is applied to a ſubſtance out of the body, in a proper temperature, it will produce changes in it, ſimilar to thoſe which take place in the commencement of digeſtion; but by applying gaſtric juice, the watery fluids of the ſtomach, the ſaliva, the bile,

bile, the pancreatic juice, altogether or ſeparately, in no caſe has chyle, or any thing like it, been formed.

It is not yet aſcertained what are the circumſtances which contribute to render different articles uſed as food, digeſtible or indigeſtible. Something is undoubtedly to be aſcribed to firmneſs of texture, ſince cuticle, horn, hair and feathers, which are indigeſtible in their natural ſtate, became digeſtible and nutritious when reduced to a gelatinous form by Papin's digeſter. That the ſolubility or inſolubility of a ſubſtance in the ſtomach is not, however, merely owing to the degree of ſolidity, is proved from a circumſtance already mentioned, viz. that boiled barley was not acted on by the gaſtric juice of a buzzard hawk, while pieces of hard beef bone, expoſed to its action in the ſame manner, were completely diſſolved. But ſubſtances may even be rendered too ſoft; for a fluid is difficult of digeſtion, and its continued uſe very injurious to the ſtomach. It may be remarked, that nature has given us very few fluids as articles of food. It therefore ſeems, that ſubſtances may be either too compact or too lax in their ſtructure, to render them fit ſubjects to be acted on by the digeſtive powers.

The degree of eaſe, however, with which ſubſtances are digeſted, ſeems in many caſes owing to a difference in ſolidity. Brain, liver, muſcle, and tendon are digeſtible in the order in which they are here inſerted. Boiled, roaſted, and even putrid meat is eaſier of digeſtion than raw. Huſks of ſeeds and the hulls of fruits are indigeſtible in their natural ſtate, but to what circumſtance this is owing is not fully aſcertained. The whole of our food is ſometimes not digeſted; this may ariſe from two cauſes, either from ſome parts of the food being of too firm a texture to

be dissolved so soon as the other parts are converted into chyle and carried into the duodenum: or from the stomach being so much disordered as to digest imperfectly. This disorder of the stomach sometimes proceeds so far, that the food passes through the body almost unchanged. In some cases food has been retained on the stomach for twenty-four hours, and thrown up without being altered in the least.

The essential oils of animals and vegetables are indigestible; they are soluble, however, either in the gastric juice or the chyle, by which means they become medicinal from their stimulant powers. The essential oils of vegetables, but more particularly those of animals, seem to pervade the very substance of the animals whose food contains much of them. Thus sea birds, which feed on fish, taste very strongly of them, and those which live on that food only during certain times of the year, as the wild duck, have that taste only at certain seasons. Two ducks were fed, one with barley, the other with sprats for about a month, and killed both at the same time; when dressed, that fed on sprats was hardly eatable.

Animals eat less in proportion as their food is more nutritious. Thus carnivorous animals require much less food than the granivorous, and these, than the graminivorous; animals, indeed, of the last kind, employ almost the whole of their time in eating. A corresponding relation is also observed with respect to the digestive organs in these several races of animals; carnivorous animals have only one stomach, granivorous animals very generally two, and graminivorous animals four stomachs, with a greater length of intestines. From which circumstances it may be col-

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lected, that graſs is more difficultly aſſimilated than grain, and grain than fleſh.

The firſt ſtomach in ruminant animals, ſuch as the bull, the ſheep, &c. is a receptacle which has a very weak action on the food, and from it the animal has the power of returning the food into the mouth, to undergo a ſecond maſtication. In Mr. Hunter's paper on Digeſtion, publiſhed by the Royal Society, there is the following curious obſervation, which illuſtrates very much the uſe of theſe previous ſtomachs: milk ſucked in by the calf does not remain in any of the previous ſtomachs, but paſſes down inſtantly into the digeſting ſtomach, not requiring any previous operation; but graſs remains for a length of time in the previous ſtomachs.

If it is allowable to extend our views beyond the animal kingdom, we might fancy that the digeſtive proceſs in vegetables is ſtill more difficult than it is in the graminivorous animals, ſince vegetables are continually taking in nouriſhment, and conſume an immenſe quantity of air and water in proportion to their growth and bulk. When vegetables, however, are furniſhed with matter which has undergone more preparation than mere air and water, viz. putrified vegetable matter, their growth is far more rapid; and they flouriſh ſtill more on the remains of the animal kingdom.

Sleeping animals do not digeſt during winter. Worms and pieces of meat were conveyed down the throats of lizards, which were going into winter quarters, and which were afterwards kept in a cool place. On opening the animals at different periods, the ſubſtances were found entire and without alteration. Some of the lizards voided them in the ſpring with little or no alteration produced in them. Di-

gestion is therefore regulated by the state of the other functions of the body *.

By hunger and custom animals may be taught to eat, and even to prefer, a very different kind of food from that naturally designed for their nourishment: thus pigeons have been made to live entirely on flesh. Whether the gastric juice is altered in its nature by a difference of food, or in what other way the system accommodates itself to such a change, it is not easy to determine.

* Hunter on Digestion.—See his volume on the Animal Economy.

Chap. XXXII.

RESPIRATION AND ANIMAL HEAT.

Reſpiration in part an involuntary Function.—Four Stages of Reſpiration.—Uſes of Reſpiration.—Reſpiration of Inſects different from that of other Animals.—The red Colour of the Blood derived from the Air in Reſpiration.—Dr. Prieſtley's Experiments.—Dr. Goodwyn's Experiments.—The oxygenous Part of the Air diminiſhed by Reſpiration.—Fixed Air generated in the Lungs in Reſpiration and expired.—Animal Heat produced by Reſpiration.—Inſtanced in different Animals.—Dr. Crawford's ingenious Theory.

UNINTERRUPTED reſpiration being neceſſary to our exiſtence, it is wiſely ordained, that this function ſhould be ſo far involuntary as not to require a continual and irkſome attention. For other purpoſes, as that of ſpeech, reſpiration is no leſs wiſely ſubmitted in ſome meaſure to our direction, ſo that within certain limits we can accelerate or retard it at pleaſure. We are ſufficiently prevented, however, from ſuſpending reſpiration to ſuch an extent as to interfere with other proceſſes abſolutely neceſſary to the ſupport of life, by being ſubjected, whenever we ceaſe to breathe, to a ſenſation inexpreſſibly diſtreſſing, and which compels us to uſe every effort in our power to inhale air into the lungs.

The thorax, or that bony caſe which ſurrounds and protects the lungs, is furniſhed with a number of muſcles, ſome of which, by drawing the ribs upwards, enlarge its capacity, and others, by drawing them downwards, diminiſh it. Its capacity, however, is ſtill more influenced by the muſcular organ called the diaphragm, which from the breaſt bone and lower ribs

paſſes

passes obliquely downwards to the loins, and separates the thoracic from the abdominal viscera. By the contraction of the diaphragm, the abdominal viscera are pressed downwards and forwards, by which the lungs are permitted to expand themselves in the same direction; when the diaphragm is relaxed, and the abdominal muscles are thrown into action, a directly opposite motion takes place; the viscera of the abdomen are pressed upwards and backwards against the lungs, from which part of the air is consequently expelled.

The air, which is to be considered as possessing many properties in common with other fluids, possesses this, that by its weight it enters where it is least resisted. Part of the resistance to the entrance of the air into the lungs being taken off by the action of the muscles dilating the thorax, it rushes in through the windpipe, in the same manner as it rushes into the cavity of bellows, when the boards are separated from each other. Inspiration and expiration therefore are not performed by the lungs themselves, since air would be equally drawn into and expelled from the cavity of the thorax when deprived of lungs, supposing that the parts of the thorax could be made to perform their motions perfectly well after death. The lungs may therefore be compared to the cavity of bellows filled with any downy substance, the bones of the thorax to the boards of the bellows, and the muscles of the thorax to the hands by which the bellows are moved.

Respiration may be divided into four stages or periods; first, inspiration; secondly, a pause when the lungs are filled; thirdly, expiration; and lastly, a pause when the lungs are emptied. We are equally stimulated to inspiration and expiration by a sensation of

uneasiness,

uneasiness, but that which is felt when the lungs are kept too long inflated after a full inspiration, is of a different kind from that which is perceived when they are preserved too long empty after expiration. In the former case the uneasiness is referred to the head, in the latter to the chest. To what these sensations are owing we cannot altogether determine; they are probably, however, to be attributed to the anterior cavities of the heart and the vessels of the head being overloaded with blood, which cannot so readily pass through the lungs while their motion is suspended. The truth of this opinion is much confirmed by the flushing of the face, and the bursting of blood vessels, which sometimes happens from impeded respiration.

The air, after passing through the windpipe, is conveyed by its ramifications to the air vessels of the lungs. After inspiration the air vessels, which are to be considered as very minute bladders with thin coats, are fully distended. The minute and very numerous ramifications of the pulmonary artery are distributed on the membranes of these air vessels; and through the membranes, without coming into direct contact with the blood, the air produces those changes on it, which are found to be absolutely necessary for the continuance of life.

The chief uses of respiration, as far as our knowledge extends, are, 1st. To effect certain changes in the mass of blood; and 2d. To produce animal heat. These effects, though no doubt intimately connected, I shall take the liberty of considering separately, for the sake of greater perspicuity.

The composition of the atmosphere has already been described, and it is at present only necessary to remind the reader, that rather less than three-fourths of the atmosphere is azotic gas, rather more than one fourth

oxygen

oxygen gas, and one or two parts in the hundred fixed air. The azote is not proved to have any effect in respiration, and seems to be merely a diluent of the oxygen gas, which is the principal agent. The fixed air contained in the atmosphere is probably also completely inert with respect to respiration. Previous to a more particular consideration of the nature of this function, it may not, however, be improper to throw together a few miscellaneous observations on that subject.

Animals breathing air contaminated by respiration, not only suffer for want of the pure part of that air, which is destroyed, but also from the fixed air which is produced. Mr. Cavendish asserts, that in certain diseases, and by certain persons, the air is much sooner rendered unrespirable. According to the observations of Dr. Priestley, insects appeared to breathe fixed air, or air otherwise contaminated, as readily as pure air. Flies, however, and other winged insects, have the property of destroying the salubrity of air by their own respiration, as may be observed by confining a few of those animals in a phial. These animals, indeed, appear less of the amphibious kind, and much more delicate, than when in the vermiform or maggot state.

Insects, and some exsanguious animals, will exist a considerable time without any thing equivalent to respiration. The same has been proved to be the case with fishes, though it is impossible to define the limits of their existence.

A vessel in which, when filled with common air, a mouse could not live more than half an hour, was filled by Dr. Priestley with vital air; a mouse then lived in it for three hours, and being taken out alive, the

the air was ſtill found better, by the nitrous teſt, than common air.

From ſome experiments made by Dr. Goodwyn, he concludes that the lungs contain 109 cubic inches of air after a complete expiration; and that this quantity receives an addition of fourteen cubic inches by inſpiration. The dilatation of the lungs, therefore, after expiration, is to their dilatation after inſpiration as 109 to 123.

One inſpiration is commonly performed for every four or five pulſations of the heart, which latter, in different healthy perſons, vary from ſixty to ninety in a minute.

The blood undergoes remarkable changes of colour when circulating in the veſſels of an animal; in the lungs it acquires a florid hue, which is gradually loſt, while the blood is paſſing through the other parts of the body, again to be reſtored in the lungs. That the red colour of blood is owing to the influence of vital air is manifeſt from actual experiment. Dr. Prieſtley introduced different portions of ſheep's blood into different kinds of air, and found always that the blackeſt parts aſſumed a bright red colour in common air, and more eſpecially in vital air; whereas the brighteſt red blood became preſently black in any air unfit for reſpiration, as fixed air, inflammable, azotic, and nitrous gas, and after becoming black in the laſt of theſe kinds of air, it regained its red colour on being expoſed to common or vital air, the ſame portions becoming alternately black and red.

It is proper, however, to mention, that Dr. Goodwyn introduced four ounces of florid blood, freſh drawn, into a glaſs receiver, containing fixed air, and confined it there for a conſiderable time; and alſo received blood from the carotid artery of a ſheep into a

phial

phial filled with fixed air, but in neither of the experiments was the florid colour altered. These experiments do not accord with those of Dr. Priestley, but the following is intirely consonant with them. Dr. Goodwyn inclosed a quantity of vital air in a glass receiver inverted in quicksilver, and introduced into it four ounces of blood, fresh drawn from the jugular vein of a sheep; the blood became instantly very florid; and after several minutes the quicksilver ascended two or three lines, which evidently proved, that while the blood was altered in colour, the air was at the same time diminished in quantity.

It is well known that blood, when it coagulates on being exposed to common air, assumes on the surface a bright red colour, while the inside is much darker, bordering upon black.

An objection, however, seems to arise to this hypothesis, viz. that though the blood in the lungs is not more than a thousandth part of an inch from the air, yet it never comes into actual contact with it. In order to examine the soundness of this objection, Dr. Priestley took a large quantity of black blood, and put it into a bladder moistened with a little serum, and tying it very close, hung it in a free exposure to the air, though in a quiescent state, and next day found, upon examination, that all the lower surface of the blood, which had been separated from common air only by the intervention of the bladder, had acquired a coating of a florid red colour, and as thick apparently as it would have acquired if immediately exposed to the open air.—In this case it is evident, that the change of colour could not have been owing to evaporation, as some have imagined. A piece of the crassamentum, surrounded by serum, acquired (not only

only on that part of the ſurface which was expoſed to the air, but in thoſe parts which were covered ſeveral inches with ſerum) a florid red, ſo that the deep covering of ſerum, which muſt have prevented all evaporation, was no more an impediment to the action of the air than the bladder. That it is really the air, acting through the ſerum, and not the ſerum itſelf, which gives the florid colour, is clearly aſcertained by the following experiment: two equal portions of black blood were put into two cups, containing equal quantities of ſerum, which covered the blood in both to the depth of half an inch. One of the cups being left in the open air, and the other being placed under the exhauſted receiver of an air pump, the former preſently acquired a florid colour, while the other continued twelve hours as black as at firſt. In another experiment, the reverſe of the former, the influence of the air upon the blood was no leſs deciſively proved; for red blood became black through the depth of two inches of ſerum, when the veſſel containing it was expoſed to azotic gas. Putrefaction, however, will produce a ſimilar effect; for a ſmall quantity of perfectly florid blood being put into a glaſs tube ſealed hermetically, and thus cut off from all communication with external ſubſtances, became black in a few days. Except ſerum, milk is the only animal fluid, through which the air can act upon blood. By ſome ſubſequent experiments made by Dr. Prieſtley, he found that the intervention of a bladder by no means prevents the action of ſome airs on each other, as the nitrous on common air, &c.

The ſame induſtrious philoſopher found alſo, that the air and blood employed in the above experiments undergo oppoſite changes; for vital air was vitiated by expoſure to venous blood, and, on the contrary, inflammable

inflammable air was abſorbed, and foul air improved, by expoſure to arterial blood. It has alſo been proved, that inflammable air will produce a change of colour in the blood, when introduced into the veins of a living animal.

The moſt remarkable change produced on air, which has been ſubſervient to reſpiration, is the diſappearance of the vital air, and the production of fixed air. On account of the production of fixed air, indeed, an animal can only breathe a given quantity of air for a certain time, after which it ſickens and dies. If a jar filled with vital air is placed over mercury, and an animal confined in it, after a time it will be obſerved to breathe with difficulty, and become very uneaſy; if the animal is then taken out, and cauſtic alkali is introduced, a great diminution in the bulk of the air will take place; by the repeated introduction of the animal and the cauſtic alkali, almoſt the whole of the air may be made to diſappear, which proves that the vital air is by reſpiration converted into fixed air.

When we conſider the compoſition of fixed air, which conſiſts of the carbonaceous principle united with oxygen, we muſt conclude that the oxygen gas is converted into fixed air by the addition of that principle, which, in a ſtate of extreme diviſion, ſeems to be extricated from the lungs. By ſome phyſiologiſts, the extrication of this noxious principle has been conſidered as the only end anſwered by reſpiration. That this is not all, however, is proved by the conſideration, that though part of the oxygenous gas is converted into fixed air by the addition of the carbonaceous principle, yet the weight of the air expired does not exceed that which is inſpired. This naturally ſuggeſted the opinion, that a part of the inſpired air was abſorbed, nearly correſponding

corresponding in weight with the matter discharged by the lungs. Dr. Prieſtley, by a ſeries of experiments recorded in vol. lxxx. p. 106. of the Philoſophical Tranſactions, has accordingly proved, that a conſiderable quantity of vital air is abſorbed by the blood. A very ſmall portion of water is alſo thrown from the lungs at every expiration, which may be either an aqueous exhalation from the lungs, or may be formed by an union of vital air with inflammable gas.

Mr. Lavoiſier aſcertained that when the air out of doors conſiſted of,

27	parts oxygen air,
73	azotic air.
100	

The air in the loweſt ward in the General Hoſpital at Paris, contained but

25	parts of oxygen air,
71	of azotic air,
4	of fixed air.
100	

This proportion varied in different parts of the room. At the top the air contained the following proportions:

18½	parts of oxygen air,
79	of azotic air,
2½	of fixed air.
100	

The production of animal heat next properly claims our attention. That reſpiration is really the cauſe of animal heat can ſcarcely be doubted; for thoſe animals which are furniſhed with lungs, and which continually inſpire the freſh air in great quantities, have the power of keeping themſelves at a temperature con-

ſiderably higher than the ſurrounding atmoſphere; but ſuch animals as are not furniſhed with reſpiratory organs, are very nearly of the ſame temperature with the medium in which they live. Among the hot animals, thoſe are the warmeſt which have the largeſt reſpiratory organs in proportion to the bulk of their bodies. This is particularly the caſe with birds, which have the greateſt degree of animal heat. In the ſame animal, the degree of heat is in ſome meaſure proportionable to the quantity of air reſpired in a given time. Thus we find, that animal heat is increaſed by exerciſe and whatever accelerates reſpiration. By the word heat I do not in this place mean a ſenſation, but caloric, or a peculiar fluid, having attractions for other ſubſtances, with which it is capable of forming combinations, and producing many important phenomena. We muſt carefully avoid eſtimating the quantity of heat or caloric contained in a body by its temperature, as indicated by the ſenſes, or even by a thermometer; for water, wax, metallic bodies, &c. in paſſing from a fluid to a ſolid ſtate, loſe a vaſt quantity of heat without any diminution of temperature; and it is well known, that a quantity of wax, &c. partly ſolid and partly fluid, is always of the ſame temperature, whether it tends towards the ſolid or the fluid ſtate; that is, whatever is the temperature of the ſurrounding medium. If the wax is in a melting ſtate, it abſorbs the ſuperfluous caloric, which becomes latent; if on the other hand it is congealing, its latent heat is continually extricated, and ſuſtains its temperature at a fixed point. Caloric may therefore exiſt in a latent ſtate, in which it cannot affect the thermometer.

There is ſtill another difference with reſpect to the quantity of heat or caloric contained in bodies, independent of any change of form, ſimilar to that which takes

place

place in the combination of heat with ice conſtituting water. This latter difference is called a difference in capacity for heat, by which is underſtood an inequality in the quantity of abſolute heat in two bodies, though their temperatures and weights are equal. Thus, if a pound of water and a pound of diaphoretic antimony have a common temperature, the quantity of abſolute heat contained in the former is nearly four times that contained in the latter.

The following is a brief ſtatement of Dr. Crawford's ingenious theory of animal heat. He made a ſeries of experiments, by which he found, that the fixed air and aqueous vapour, which are diſcharged from the lungs, contain only about one-third part of the abſolute heat contained in the atmoſpherical air, previous to its being reſpired: air, therefore, in becoming ſubſervient to reſpiration, loſes *part* of its heat. He has alſo ſhewn that the abſolute heat of florid arterial blood is to that of venous nearly as eleven and an half to ten; ſince, therefore, the blood, which is returned by the pulmonary veins to the heart, has its quantity of abſolute heat increaſed, he fairly concludes that it muſt have acquired this additional heat in the lungs. From the preceding obſervations it appears, that the production of animal heat depends on a proceſs analogous to chemical elective attraction, and which is regulated by the following principles. Vital air contains more abſolute heat, in proportion to its temperature and weight, than fixed air. The blood is returned to the lungs impregnated with the carbonaceous principle; the blood has leſs attraction for that principle than vital air has; in the lungs, therefore, it quits the blood to unite with the vital air. By this combination the vital air is changed into fixed air, and depoſits part of its heat: the capacity of blood for heat

is at the fame time increafed; the blood therefore receives that portion of heat which was detached from the air.

The arterial blood, in its paffage through the capillary veffels, is again impregnated with the carbonaceous principle, and the bafis of inflammable air, by which its capacity for heat declines; it, therefore, in the courfe of the circulation, gradually gives out the heat which it had received in the lungs, and diffufes it over the whole body. Thus it appears, that in its circulation through the lungs the blood is continually difcharging carbonaceous matter and abforbing heat, and that in its paffage through the other parts of the body it is perpetually imbibing carbon and emitting heat. In this account of animal heat I have entirely omitted the abforption of vital air. This abforption was not admitted by Dr. Crawford, and, though eftablifhed by the experiments of Dr. Prieftley, does not at all invalidate the theory of the former philofopher. It is confiftent with either hypothefis, that the blood in the lungs gains the heat which is loft by the air; and upon the truth of this propofition refts the theory of Dr. Crawford.

By the different capacity which blood poffeffes for heat in its different ftates, it is capable of fupplying the different parts of the body with heat, while its own temperature remains the fame. If this difference of capacity for heat did not exift, the extremities of the body could not be properly fupplied with heat from the lungs, unlefs the lungs themfelves were expofed to a degree of heat which would be certainly prejudicial, and, perhaps, fuch as no organifed fubftance could fupport without deftruction.

Dr. Crawford has moreover proved, by a courfe of experiments, that when an animal is placed in a cold

medium, the venous blood acquires a deeper hue; that a greater quantity of air is vitiated in a given time, and, consequently, that more heat is absorbed by the blood. It appears, therefore, that nature has in this, as in many other instances, connected the occasion with the means of supplying it. Since, therefore, it is proved, that heat is absorbed from the air in respiration, and since the quantity absorbed is not only adequate to the purpose, but proportioned to the occasion, we may consider ourselves as greatly indebted to Dr. Crawford for having thrown great light on a most important function, but which must still be enumerated, on some accounts, among those obscure processes of nature, on which human ingenuity may exert its powers, but which it can probably never completely reveal.

The analogy between combustion and respiration cannot fail to strike every person acquainted with the nature of these processes. Air, in which a candle has remained till extinguished, is incapable of supporting animal life. On the other hand, air, in which an animal has remained till it expired, will not support the flame of a candle. In both these cases heat is lost by the air employed; because gasseous compounds are formed which have less capacity for heat than oxygen gas possesses. There is one remarkable difference, however, between combustion and respiration; in combustion, the heat derived from the air becomes immediately perceptible, and frequently rises to an intense degree. In respiration, however, the heat is gradually evolved, in consequence of an admirable law of the animal economy, which has already been adverted to in explaining Dr. Crawford's theory of animal heat.

What oily and spirituous substances are to a lamp they are also to the animal body, and no animal is capable of subsisting for a considerable time without

 food

food containing ſome portion of theſe principles. This is particularly obvious with regard to the food of carnivorous animals, and it is no leſs certain that grain and even graſs contain the ingredients of oil and ſpirituous liquors. Our food may therefore be conſidered as fuel, and animal heat as a gentle combuſtion. Hence, ſuch perſons as eat and drink large quantities of inflammable ſubſtances, increaſe the heat of their bodies beyond the proper ſtandard, and in ſcientific as well as common language, may be ſaid to burn themſelves up. This conſideration may ſerve to confirm the eſtabliſhed practice of withholding from febrile patients the uſe of inflammable matters as food, and of giving acids, the nature of which is directly oppoſite. Towards the end of ſome fevers, however, particularly typhus, when the heat ſinks below the proper ſtandard, brandy and æther are found to be highly uſeful.

In the Medical Extracts, in which there are ſome ingenious and new obſervations on this ſubject, it is mentioned that Dr. Withering wrote to Dr. Beddoes to the following effect:—The late Mr. Spalding, who did ſo much in improving and uſing the diving bell, was a man of nice obſervation, and had he not fallen a ſacrifice to the negligence of drunken attendants, would have thrown much additional light upon more than one branch of ſcience. He particularly informed me that when he had eaten animal food, or drank fermented liquors, he conſumed the air in the bell much faſter than when he lived upon vegetable food and drank only water. Many repeated trials had ſo convinced him of this, that he conſtantly abſtained from the former diet whilſt engaged in diving.

CHAP. XXXIII.

THE VOICE.

Instrument of the Voice in the Animal Body.—The Larynx.—Experiments on the Windpipes of different Animals.—Whether the Larynx acts as a wind or stringed Instrument.—Singing, how performed.—Speaking.—Whispering.

ALL animals, as far as our observations extend, have the power of communicating their sensations or ideas to each other, and the principal means of this communication is the voice. Man is indebted to this function for the satisfaction of social intercourse, and in a great measure also for his distinguished pre-eminence above other animals in mental acquirements.

The instrument of the voice is the larynx, and the immediate occasion of it is, the expulsion of the air from the lungs through this organ exciting a vibratory motion in the whole larynx, but more particularly in the ligaments which pass from the scutiform to the arytenoid cartilages. That the larynx is really the instrument of the voice has been fully proved by an ingenious anatomist * of our times, who, after detaching the windpipe from the bodies of different animals, by relaxing or shortening the tendinous bands at the extremity of the windpipe, and blowing in at the opposite end, found means to produce all the different cries and tones of which the living animals were capable. On the different structure of the larynx depends the different voices of animals; thus birds, which have a shrill

* Ferrein.

and piercing note, are found to be poſſeſſed of a narrow larynx; animals, which are hoarſe or mute, of a wide one. The ſame fact is proved in ourſelves. We may perceive, by applying the finger to the throat, when we endeavour to produce a ſhrill tone, that the larynx is contracted, rendered tenſe, and elevated; when we produce a grave ſound, it is enlarged, relaxed, and depreſſed; by endeavouring to produce a graver tone than we are capable of, the larynx is too much relaxed to perform its office, and the air paſſes through it without producing any ſound whatever.

Bonnet obſerves, that birds are furniſhed with what may be called two larynxes, the one at the ſuperior extremity of the windpipe, as in men and quadrupeds; the other (which is the principal organ of ſound with them) at the inferior extremity, and cloſe to the bronchiæ. The chief inſtrument for the modulation of the voice in this lower larynx is a membrane ſituated tranſverſely between the two bronchiæ, communicating with other membranes, reſembling the reed of a hautboy. On the greater or leſs elaſticity of theſe membranes depends the tone of the voice, in the ſame manner as in other animals it depends on the tenſion or relaxation of the cords of the glottis *.

It has been much debated, whether the larynx, in producing the voice, acts as a wind or a ſtringed inſtrument; but there can be little doubt, from the ſtructure and motions of the larynx, that it poſſeſſes the advantages of both.

Singing is a modulation of the voice, through various degrees of acuteneſs and gravity, and is performed almoſt ſolely by the larynx, though the noſe and mouth are in ſome degree concerned in improving and ſoftening the tones. During ſpeech, the larynx is

* Bon. Cont, p. 7.

is pretty much at reſt, as very little variety, with reſpect to gravity or acuteneſs of voice, is requiſite. The voice being produced in the larynx, is afterwards formed into letters, ſyllables, and words, by various motions of the tongue and lips. The larynx is very little, if at all, employed in whiſpering, and ſeems to tranſmit the air in this caſe as a ſimple tube, like the windpipe.

Chap. XXXIV.

MUSCULAR MOTION.

Inquiry whether any Thing equivalent to muſcular Motion is to be found in the other Parts of Creation.—Different Hypotheſes concerning the Cauſe of muſcular Motion.—Its Dependence on the Will.—Contractile Power of Muſcles after Death.—Extent of the Contraction of Muſcles.—Advantage from the Obliquity of certain Muſcles.—Inſertion of the Tendons.—Force of Muſcles.

THE power of contraction, with which the muſcles of animals are endued, and by which they perform all the motions of the body, is different from any property inherent in any other kind of matter. But though the moſt remarkable examples of muſcular contraction are obſerved among animals, yet we are by no means authorized to conclude, that the vegetable kingdom is wholly deſtitute of ſimilar powers; on the contrary, the expanſion and contraction of the flowers and leaves of plants, according to the degree of heat, and the circulation of their ſap, are ſtrong arguments in favour of the opinion that they are furniſhed with organs truly muſcular; and the convulſive motions excited by touching the ſtamina of certain plants ſeem to place this matter beyond diſpute.

Under the head of anatomy, the general outlines of the ſtructure of the muſcular organs have been already conſidered; but nothing further was advanced on the preſent ſubject, than that muſcles are contractile maſſes compoſed of numerous minute, and in general

general red *, fibres, combined together in bundles by cellular ſubſtance. Such, therefore, being the ſtructure of muſcles, little credit appears to be due to the ſuppoſition, that muſcular contraction depends on an influx of blood or any other fluid into minute bladders or cells; and it muſt remain undetermined, whether the ultimate moving fibres are tubular or ſolid; whether they conſiſt of chains of rhomboidal veſſels, as has been imagined by ſome phyſiologiſts, or whether, as others have thought, they contain a kind of down or woolly ſubſtance.

When muſcles are thrown into action, they become ſhorter, broader, and more denſe, or ſolid, to the touch; their bulk does not ſeem to be on the whole increaſed, nor are they found to be of a paler colour.

Muſcles never act but from ſome exciting cauſe; of theſe one of the moſt frequent and curious is volition, by which every day's experience teaches us we have the power of throwing the greater number of our muſcles into action. Over ſome of our muſcles, however, as thoſe of the inteſtines, and the heart, the will has no influence, and theſe are therefore called muſcles of involuntary motion. What is the nature of the influence which the will exerts over muſcles, we can never hope to diſcover; but it is of importance to remark, that the nerves are the organs by which this influence is exerted; for the nerve leading to any particular limb being divided, we are no longer able to move that limb at our pleaſure.

Beſides, however, being influenced by the will, muſcles are thrown into action by ſeveral other cauſes,

* The colour proceeds from the blood, which they contain in minute veſſels.

ſuch

ſuch as chemical or mechanical injury, and ſtill more remarkably by the electric ſhock, which influences muſcles inſenſible to every other known ſtimulus.

Muſcles retain a contractile power for a conſiderable time after they are removed from the living body; this power, however, gradually diminiſhes, till, ſooner or later, according to a variety of circumſtances, it ceaſes altogether. The muſcles of involuntary motion, when removed from the reſt of the body, retain their contractile power longer than thoſe of voluntary motion; the former, indeed, from this circumſtance, as well as from their uninterrupted motion in the living body, ſeem to be poſſeſſed of a capacity for contraction beyond that of the other muſcles.

What has been hitherto ſtated, relates principally to the more remarkable muſcular contractions, by which the actions of the body are performed; but it is to be remembered, that beſides theſe occaſional contractions, there is a continual tendency in the muſcular fibre to ſhorten itſelf; and even after death, when a muſcle is divided, the wounded extremities recede from each other. A ſtrong illuſtration of this circumſtance is obtained, by obſerving the conſequence of dividing a muſcle in the living body, for in this caſe its antagoniſt will conſtantly draw the part which theſe muſcles were deſigned to move, towards its own ſide.

That power by which the different parts of a muſcle, divided after death, recede from each other, is called the vis mortua, and is common to muſcles and other animal fibres. The power by which a muſcle obeys a ſtimulus after being ſeparated from the body, or after its communication with the ſenſorium has been cut off by other means, as by dividing or tying its nerves,

has been called its vis insita. This power is more peculiar to life; and though it may continue for a few hours after death, yet it disappears much sooner than the former. It was supposed by Haller to exist wholly independent of the nerves, but this opinion has neither been established nor refuted. The capacity of muscles to obey the influence of nerves, is called the vis nervea. The power which we possess of calling the muscles into action by a voluntary effort, depends on a relation established by God, and not on the directing influence of the human soul, since we have no conception of the intimate structure either of the nerves or muscles. It is true, that by habit we acquire a more exact command over our muscles in most instances, yet the operation of sucking, in which a variety of muscles operate in a complex manner, is performed by a new-born infant; and the young of many animals can walk immediately after birth.

The extent of the contraction of a muscle has been limited by some anatomists to one-third of its length. This statement, however, though it may be nearly just with respect to the greater number of muscles, is by no means true with respect to all. The muscular coat of the bladder, for example, will admit of that organ containing a quart of fluid matter, without much inconvenience, and at the same time is so contractile as to be capable of expelling almost every drop in a very short time.

But the extensive effect of muscular contraction is not owing only to the degree to which a muscle can shorten itself, but also to the direction of its fibres. Thus oblique muscles produce a much more extensive motion than those which are strait, and this extensiveness of motion is proportioned to the obliquity of the muscle.

muſcle. What is gained, however, in extenſiveneſs of motion by the obliquity of fibres, is loſt in force; but this is more than compenſated by the oblique ſtructure allowing ſpace for a much greater number of muſcular fibres. Oblique muſcles have therefore in both reſpects the advantage over thoſe which are ſtrait, and are accordingly much more numerous in the animal machine.

There is no part of the ſtructure of the animal body, which is more calculated to excite our admiration, than the manner in which the tendons of muſcles are inſerted into the bones. If, for inſtance, the muſcle called the biceps, which lies at the inſide of the os humeri, and which is deſigned to bend the fore-arm, inſtead of terminating at the upper part of the radius, had been inſerted half way between the elbow and wriſt, it is evident, that when the muſcle had contracted itſelf ſo as to bring the fore-arm to a right angle with the os humeri, the tendon muſt have ſtarted ſeveral inches from its place, and have given the limb a very unpleaſant appearance, and muſt alſo have been attended with ſeveral real inconveniences. By the tendon, however, being inſerted near the joint, the motion of the limb is performed without ſo great a riſing of the tendon as to prove troubleſome. By this ſtructure moreover, the motions of the limb are much quicker than if the tendon had been inſerted lower down towards the wriſt. By the tendon being inſerted nearer the axis of motion, it is alſo evident, that a much ſmaller contraction of the muſcle is ſufficient to produce an effect, than muſt have been neceſſary to produce the ſame had the inſertion of the tendon been half way between the elbow and the wriſt. That univerſal rule in mechanics, however, that what is gained in velocity

city is loſt in force, it muſt be remarked, is applicable to this caſe, ſo that ſome loſs of ſtrength neceſſarily attends the acquiſition of ſuperior celerity. But this inconvenience has been obviated by a very ſimple expedient, that of making the muſcle ſtronger than would otherwiſe have been neceſſary.

Many very erroneous calculations have been made with reſpect to the force of muſcles. Borelli has been led to conclude that the heart at every contraction exerts a force equal to 100,000lb. while others have pretended to diſcover that this force does not amount to many ounces. With reſpect to the heart, however, we really have not data on which we can proceed with any tolerable degree of preciſion. There is no muſcle in the body more conveniently ſituated for having the force of its contraction determined than the biceps of the arm. It will be foreign to our preſent purpoſe to mention all the ſteps of the calculation, with the groſs reſult of which I ſhall in this place preſent the reader; it is indeed merely mentioned as probable, that when we raiſe forty pounds weight by means of the fore-arm, the biceps exerts a force at leaſt equal to five or ſix hundred pounds.

The ſurprizing muſcular force of the turkey's gizzard, has been already noticed.

From theſe obſervations, it appears, notwithſtanding the great viſible exertions of muſcular force, that the greater part of their real power produces no apparent effect. For all muſcles are inſerted nearer the center of motion than the weights on which they act, and their effect is therefore leſs in proportion to the ſhortneſs of the lever on which they act. In moſt of the limbs the muſcles are inſerted at very acute angles, which throws their force more nearly in the direction

of

of the center of motion, and consequently lessens their effect. Many muscles pass over projecting bones, which increase friction. But besides all these causes diminishing the power of muscles, one half of their strength is exerted on their fixed extremity; for a muscle in action, like an extended cord, exerts an equal force at both extremities.

CHAP. XXXV.

ANIMAL ELECTRICITY.

Accidental Diſcovery of M. Galvani.—Animal Electricity only excited by Metals.—Experiments on dead Animals.—Conductors and Non-conductors of this Power.—Experiments on the living Subject.—On Earth Worms, &c.—Analogy between this Power and Electricity.—Shock of the Torpedo.—Nervous Energy.

AMONG the late diſcoveries in philoſophy, there is not any more curious than that relation which is found to exiſt between certain metals and the nervous and muſcular ſyſtem of animals, which has received the name of animal electricity. How far it is conſiſtent with truth to refer this influence to the laws of electricity may be a proper ſubject of inquiry, and perhaps of ſcepticiſm; but it will be neceſſary previouſly to relate the principal facts which have been aſcertained on a ſubject ſo novel in phyſiology, and ſo little analogous to the known principles of animal exiſtence.

The ſhock which the muſcles of the human frame receive from the touch of the torpedo, and of the electrical eel, had long been known; but that the animal fibre when deprived of the principle of vitality ſhould be ſubject to a ſimilar influence, was a diſcovery reſerved for the preſent age. M. Galvani, the profeſſor of anatomy at Bologna, obſerving one day certain involuntary contractions and motions in ſome frogs, which, with little credit to the profeſſor's humanity, had been hooked by the back-bone and ſuſpended from the iron paliſadoes of his garden, his curioſity was powerfully excited, and on examining mi-

nutely into the cause of these contractions, he found that he could produce them at pleasure, by touching the animals with two different metals at the same time in contact with each other.

From later observations it seems to be sufficiently ascertained that these involuntary contractions cannot be excited by any substances whatever, whether solid or fluid, except the metals, and that the mutual contact of two metals with each other is, in every case, necessary to the effect. Zinc has been found by far the most efficacious, especially when in contact with gold, silver, molybdena, steel or copper, although these latter excite feeble contractions when in contact only with each other. Next to zinc, tin and lead seem to be the best excitors. When the pieces of metals employed, and the surface of the animal fibre with which they are in contact, are large, the contractions excited are in general more considerable, but by no means in proportion to these circumstances.

In order to observe the phenomena in question, cut off the head of a frog. When it has ceased to struggle, apply a plate of zinc under its body, and a plate of gold to the superior surface. Then slide the gold plate till it comes in contact with the zinc, when the muscles which are further from the brain and spinal marrow than the metals, will be visibly agitated.

This effect will take place, although the frog with the metals are placed on an inverted glass jar, and a stick of sealing-wax is interposed between the hand of the operator and the metals, that is, although the animal as well as the metals is insulated. I mentioned gold as being the most powerful of the metals, but a plate of silver, a crown-piece for instance, will answer the purpose.

Cut off the thigh of a frog, just killed, close to the body,

body, and lay bare the ſciatic nerve. Place the nerve in contact with a piece of zinc, and let its foot reſt on a piece of ſilver; on bringing the two metals into contact, the muſcles of the limb will be convulſed.

If a piece of braſs wire is made to touch at the ſame time the metals diſpoſed as above deſcribed, a communication will be formed between them, and the contraction of the muſcles will equally take place.

If the nerve is made to reſt on a piece of zinc, and the zinc is touched with a plate of ſilver held in one hand of the operator, while with the other he takes hold of the foot of the frog, the influence will paſs through the body of the operator, and the limb will alſo be convulſed.—Theſe experiments muſt be performed before the nerve becomes dry by expoſure to the air.

In order that theſe contractions ſhould be produced, it is not neceſſary that either of the metals ſhould be in actual contact with the animal in which the convulſions are to be excited; as the interpoſition of pieces of boiled or putrid beef were found by Dr. Monro not to prevent the effect.

By an experiment of Dr. Fowler the ſame fact is proved. He found that if a frog, of which the head ſhould be firſt cut off, is divided into two parts, juſt above the origin of the ſciatic nerves, and put into a baſon of water, the hind legs may be thrown into ſtrong contractions, by bringing zinc and ſilver into contact with each other, at the diſtance of at leaſt an inch from the divided ſpine, ſo long as they are kept nearly in a line with it. Water in this caſe is the only communication between the metals and the origin of the nerves.

Dr. Fowler remarks, that he has frequently paſſed this influence through a great length of thin braſs wire, and through the bodies of five perſons communicating with each other by dipping their fingers in baſons of water placed between them; yet it did not appear to have loſt any of its force in this long and diffuſed paſſage; for the contractions excited in the frog's leg were equally ſtrong, as when it had paſſed only through one perſon. Dr. Fowler made many experiments in order to diſcover what ſubſtances were conductors and what non-conductors of this influence. He found that all metals when pure were excellent conductors; that they were not quite ſo good when in the ore; and as far as he could aſcertain, leaſt ſo when in the ſtate of metallic ſalts. From trials which he made with ſome of the calces of metals he concludes, that in that ſtate their capacity as conductors is quite deſtroyed. Stones ſeemed to be poſſeſſed of no conducting power. The different non-conductors of electricity were found to be non-conductors of this influence. Living vegetables afforded it a ready paſſage, probably from the fluids which they contain. Oils of all kinds were ſo far from conducting, that if the fingers of the perſon holding either the probe or the zinc have perſpired much, even this operates as a complete obſtruction to the paſſage of the influence; the inſtant the perſpired matter has been wiped away, and the fingers have been dipped in water, it again paſſes and excites contractions. Dr. Fowler wiſhed to aſcertain whether it paſſed over the ſurface or through the ſubſtance of metals; he coated ſeveral rods of different metals with ſealing-wax, leaving nothing but their ends, by which they were held, uncovered. Contractions were excited as readily through the medium of theſe, as if they had not been coated. It ſeems to meet with no obſtruc-

tion

tion in paſſing from link to link of ſeveral chains, even when no preſſure, except that of their own weight, is uſed to bring them into contact. Dr. Fowler was led from this to hope, that he ſhould be able to make it paſs through a very thin plate of air. He therefore coated a ſtick of ſealing-wax with a plate of tin-foil, and then made an almoſt imperceptible diviſion acroſs it with a ſharp pen-knife; but even this interruption of continuity in the conductor was ſufficient effectually to prevent its paſſage.

Dr. Fowler next proceeds to examine whether the capacity of different ſubſtances, as conductors or non-conductors, was at all affected by differences of their temperature; but this was not the caſe with zinc, iron, water, coal, or a common crucible, the only ſubſtances with which he tried the experiment.

The effects of this influence may be felt in ourſelves by a very eaſy experiment. If a piece of lead is applied to the upper part of the point of the tongue, while a piece of ſilver is applied to the under part, upon bringing the two metals into contact, a ſomewhat pungent ſenſation will be felt, accompanied by a ſtrong metalline taſte of ſome duration. The ſame ſenſation takes place though both of the metals are prevented from touching the tongue by the interpoſition of moiſtened paper.

Dr. Fowler ſays, he could never perceive that the ſenſes either of touch or ſmell were in the leaſt affected by the metals; but the effect which they produce on they eye is very remarkable. Having laid a piece of tin-foil on the point of his tongue, he placed the rounded end of a ſilver pencil-caſe againſt the ball of his eye, in the inner canthus, and ſuffered them to remain in theſe ſituations till the parts were ſo accuſtomed to them, that he could examine the ſenſations pro-

duced; he then brought the metals into contact with each other, and, to his surprise, perceived a pale flash of light diffuse itself over the whole of his eye. His tongue was at the same time affected with a similar sensation to that produced when both of the metals are in contact with it. On darkening the room the flash became more distinct and of a stronger colour. If the experiment is made with zinz and gold, instead of tin-foil and silver, the flash is incomparably more vivid. By insinuating a rod of silver as far as possible up the nose and then bringing it into contact with a piece of zinc placed upon his tongue, he also succeeded in producing the sensation of a flash of light, rather more vivid than when the silver was in contact with the ball of the eye. Dr. Fowler also mentions that his friend, Mr. George Hunter of York, discovered that by placing one of the metals as high up as possible between the gums and the upper lip, and the other in a similar situation with regard to the under lip, a flash was produced as vivid as that occasioned by passing one of the metals up the nose, and placing the other upon the tongue. It differs, however, from the flash produced in the other way, in the singular circumstance of not being confined to the eye alone, but appearing diffused over the whole face. On repeating the experiment myself, and attending to the concomitant sensations produced by this disposition of the metals, I perceived that a sense of warmth, at the instant that they were brought into contact, diffused itself over the whole upper surface of the tongue, proceeding from its root to the point. Dr. Rutherford, to whom Mr. Hunter had communicated this experiment, remarked, on repeating it, that a flash is produced not only at the instant the metals are brought into contact, but likewise at the instant of their separation; while they re-

main

main in contact no flash is observed. These curious phenomena demonstrate the free communication which subsists between the several branches of the fifth pair of nerves.

The following curious fact is also taken from Dr. Fowler's ingenious and entertaining book on animal electricity. He laid a leech on a crown-piece of silver, placed in the middle of a large plate of zinc. The animal moved its mouth over the surface of the silver without expressing the least uneasiness; but having stretched beyond it and touched the zinc plate with its mouth, it instantly recoiled as if in the most acute pain, and continued thus alternately touching and recoiling from the zinc, till it had the appearance of being extremely fatigued. When placed wholly upon the zinc, it seemed perfectly at its ease; but when at any time its mouth came in contact with the silver lying upon the zinc, the same expression of pain was exhibited as before. With the earth-worm he found that the experiment succeeded still more decisively. The animal sprang from the zinc in writhing convulsions; if, when the worm stretched itself forwards, one of the folds came upon the zinc, it expressed little uneasiness in comparison of what it shewed when the point of its head touched the zinc.

Whether this influence, whatever it may be, is derived from the metals alone, or whether the animals contribute to its production, is not easy to determine.

On re-considering the phenomena exhibited by this newly discovered influence, we shall perceive that in some respects it remarkably resembles electricity, and in others as remarkably differs from it.

Like the electric fluid, it stimulates muscles to contraction. Like that, its progress is arrested by glass, sealing-wax, &c. while it is conducted by metals,

 moisture,

moiſture, &c. Dr. Valli informs us, that he obſerved the hairs of a mouſe, attached to the nerves of frogs by the tin-foil with which he ſurrounded them, alternately attracted and repelled by each other, whenever another metal was ſo applied as to excite contractions in the frogs.

Like the electric fluid, it excites a ſenſation of pungency in the tongue; and paſſes with ſimilar rapidity through the bodies of animals.

It differs from the electric fluid in many reſpects.

In order to excite the electric power, it is neceſſary that there ſhould be motion or friction between two ſubſtances, an electric and a conductor. Animal electricity is produced by two metals, which are both conductors and without friction.

According to Dr. Fowler, charcoal is a better conductor of electricity than the fluids of animal bodies. Whereas he never could make the influence in queſtion paſs through charcoal.

Dr. Fowler in oppoſition to Dr. Valli alledges, that he could not obſerve that the niceſt electrometers were affected by this influence.

The ſame author remarks, that the moſt important and characteriſtical difference which he has yet been able to diſcover between this new influence and electricity, conſiſts in their effects upon the contractile power of animals and of plants. The contractions of animals excited by electricity, have a tendency to deſtroy that power upon which contractions depend. But the contractions excited by the application of the metals, have in all his experiments had the directly oppoſite effect. The more frequently contractions have been in this way excited, the longer they continue excitable; and the longer are the parts upon which ſuch experiments are made, preſerved from putridity.

It

It is faid that a ftream of electricity paffed through a fenfitive plant, produces an almoft immediate collapfe of its leaves; but the influence in queftion produced no fuch effect in an experiment made by Dr. Fowler.

The fame attentive experimentalift electrified both pofitively and negatively frogs, whofe heads had been feparated from their bodies. In thefe circumftances the effects of the influence in queftion took place in the fame manner and degree as when no artificial electricity was prefent.

When there is a breach of equilibrium in the diftribution of the electric fluid, all that is required in order to reftore the equality of diftribution, is the interpofition of a fingle conducting fubftance between the place in which it abounds, and that in which there is a deficiency; whereas if the phenomena of animal electricity are to be attributed to the fame caufe, it does not appear why *two* conducting fubftances fhould be neceffary.

In eftablifhing a communication between two oppofite electricities, as, for example, between the two fides of a charged phial, it is matter of indifference to which the conductor is firft applied; but it is by no means fo, in producing the phenomena of animal electricity; for if one branch of a conductor is applied to the tin-foil arming a nerve, before the other branch has been applied to the mufcles, it frequently fails to excite contractions. If firft applied to the mufcles, this is very feldom the cafe.

From fome trials which Dr. Fowler made with the artificial and natural loadftones, and a very fenfible magnetic needle, he faw no reafon to fuppofe that this new influence was in any way connected with magnetifm.

Animal

Animal electricity is even found to differ, in some respects, from that power by which the torpedo, gymnotus, &c. produce their shocks. We are told by Mr. Cavendish, that Mr. Walsh found that the shock of the torpedo would not pass through a small brass chain. It resembles the power of the torpedo, however, in producing its effects almost equally well, when both it and the subject upon which it acts are insulated from surrounding conductors. The shock of the torpedo, &c. seems to depend entirely on the will of the animal; but the will of the animal has no share in the production of the phenomena discovered by Galvani.

That this influence is not the same with the nervous energy appears from its not being stopped by a tight ligature, or by the transverse incision of a nerve, provided its parts are again brought into close contact. The nervous energy is effectually stopped by a tight ligature or a transverse incision; and placing the divided extremities into the closest contact, has no effect in restoring its influence on the parts of the body to which the divided nerve was distributed.

On the whole, it may be remarked, that the influence discovered by Galvani resembles electricity more than any other known law of nature. But it differs in so many instances even from it, that in the present state of our knowledge, we must consider it as a newly discovered law in nature; though future experience and more extensive observation may lead to a different conclusion.

CHAP. XXXVI.

SENSATION.

Difficulty of the Subject.—Sensation the Effect of certain Relations established by the Creator.—Objects of different Senses.—Influence of the Nerves in conveying Sensations to the Brain.—The Brain the Repository of Ideas.—Instinct of Animals as connected with the nervous System.—Harmony of the Senses.—Duration of sensible Impressions.—The Five Senses.

FROM the consideration of the other functions to that of sensation, the transition must be abrupt and without gradation. We now enter on a subject above all others the most intricate and difficult, and on which, since reason is engaged in discovering the source whence it derives those ideas on which it acts, we must necessarily reason in a circle.

Sensation is the link by which the Deity has connected the material to the immaterial world. Without sensation, in vain would the stars have bespangled the firmament of heaven, in vain would that glorious object the sun have been appointed to illuminate and cherish the productions of the earth; they could have been nothing to beings who must have been unconscious even of existence: and the material world would have been a work without utility or design.

Sensation is the consequence of certain established relations between objects; of these relations we can give no account, for they appear equally above our comprehension with the principles of gravitation, electricity, or magnetism. Relations between the matter of light, the objects of vision, and the eye, produce

produce ſight; relations between certain vibrations of the air and the ſenſorium of the ear produce hearing, and ſo of the other ſenſes. We by no means, however, can pretend, in any of theſe caſes, to determine all the intermediate cauſes and effects between the quality in a body, which renders it an object of ſenſation, and the perception in ourſelves; nor are we by any means authorized to conclude, that our perceptions are juſt emblems of the objects which occaſion them. But this circumſtance, upon which ſo much has been ſaid, can be to us of little importance, ſince it ſtill remains equally true, that our ſenſations are regulated by fixed laws eſtabliſhed by the Deity himſelf, and ſince we muſt ſuppoſe that the Creator of the univerſe has ordered all things in wiſdom and goodneſs.

We are ignorant of the means by which the objects of ſenſation affect the body; but the moſt obvious and ſimple idea that we can form on this ſubject is, that they act by impulſe. Thus the rays of light are known to travel with aſtoniſhing velocity, and to poſſeſs a power of moving light bodies. Sound is a tremulous motion of the air, capable of being communicated to bodies in harmonic proportion with it. Odorous particles require the aſſiſtance and motion of air to affect the organs of ſcent. The objects of taſte are more perfectly perceived by being preſſed between the tongue and palate. In order to feel any thing, it is neceſſary that the ſkin ſhould be preſſed againſt it with a certain degree of force, or, what is ſtill more effectual, rubbed over its ſurface.

The inſtruments, which are deſigned to convey the effects produced by material objects on the organs of ſenſation to the brain, are the nerves, which have been already deſcribed as diſtributed to the ſeveral parts

of the body, and more particularly to the organs of fenfation. What is the difference of ftructure, which adapts the feveral nerves to the feveral organs of fenfation, we know not, nor can we determine whether certain parts of the brain correfpond with the nerves connected with certain organs of fenfation, and are deftined to preferve the ideas received by thefe particular organs, or whether the whole brain is common to the whole ftock of our ideas and fenfations; though thefe have been fubjects of much fpeculation, it has not even yet been afcertained, whether any material impreffion whatever takes place in the brain in confequence of impreffions on our fenfes; and until this queftion is determined, we cannot be prepared to examine the other. That the brain, however, is really in fome way or other the repofitory of our ideas, we may venture to conclude, fince a perfon who lofes an organ of fenfation does not lofe the ideas previoufly acquired by it; and fince perfons fometimes complain of pain, feated in the extremity of a limb of which they have long fince been deprived.

There have been of late years fome curious fpeculations among philofophers with refpect to the material caufe of inftinct in animals, and as there is fome plaufibility in their reafonings, it may be worth while briefly to mention the outlines of their fyftem. They fuppofe that the motions of animals, commonly called inftinctive, arife from a connection of the nerves belonging to different parts in the brain. In this manner, when the young bird hears the call of its mother, and opens its beak, they fuppofe this effect to be owing to an original connection between the auditory nerve and the nerves communicating with the mufcles employed in opening the bird's beak. When a new-born quadruped performs the complex action of fucking, in

conſequence of the application of its noſe to the teat of its mother, they attribute its capacity for executing a function, in which ſo many muſcles are employed, to a connection originally exiſting between the nerves of its noſe and thoſe which belong to the organs employed in ſucking. The moſt complex inſtinctive actions of animals, according to theſe philoſophers, may be explained on the ſame hypotheſis.

The qualities of bodies, as perceived by one ſenſe, are very frequently connected with others perceived in the ſame bodies by the other ſenſes: thus, apparent unevenneſs of ſurface, is united with a roughneſs to the touch; apparent vibration, with ſound; and there is a certain analogy between the odours and taſtes of many bodies. Theſe concluſions, however, are to be referred to our previous experience, and by no means authorize us to think that there is any ſimilitude in the mode of perception between the ſenſes of ſeeing and hearing, ſeeing and feeling, or taſting and ſmelling. It is ſaid, that there have been perſons who could diſtinguiſh colours by the ſenſe of feeling; but if they did, it muſt evidently have been from ſome difference of roughneſs, ſmoothneſs, &c. reſulting from the materials employed in colouring, and not from any property inherent in the different colours as objects of ſight.

It is ordained by our Creator, for the moſt important purpoſes, that our ſenſations ſhould not be too evaneſcent; and it requires ſome time after one impreſſion is made on an organ of ſenſe, before that organ can receive another. This is proved by a very ſimple and deciſive experiment. All of us have probably obſerved, when a ſtick lighted at one end, or a coal, is whirled round with a certain degree of velocity, that the whole circle which it performs appears equally illuminated,

minated, and that we cannot determine at what point of the circle the fire really is, and the ſame circumſtance may be obſerved in the blending of colours, which are yet marked diſtinctly on a wheel before it is turned. The evident cauſe of theſe appearances is in the eye; and in the firſt caſe, when we fix our eye on any point of the circle made by the evolution of a lighted coal, the illuminated object again returns to that point before the ſenſation previouſly produced is worn off: and the blending of the colours on a wheel is explained in the ſame way; for the impreſſion made by one colour remains till the other arrives and mixes with it. It is alſo well known, that perſons who have the beſt and quickeſt ears for muſic cannot judge accurately of more than a certain number of notes in a ſecond of time. Innumerable facts, indeed, may ſerve to convince us, that the mind cannot well attend to two or more ſenſations at the ſame time *. Hold your tongue, ſaid a Frenchman, you talk ſo I cannot taſte my meat. The Frenchman was certainly right; for attention of mind is not leſs neceſſary to full perception, than a healthy ſtate of the organ of ſenſe.

All authors are agreed, that our knowledge of external objects is entirely acquired through the medium of ſenſation, though ſome perſons of the higheſt rank in literature and philoſophy ſtill contend, againſt Mr. Locke, in favour of the exiſtence of certain innate and

* The contemptible vanity of Cæſar, in pretending to perform ſeveral mental operations at once, proceeded from a real ignorance of the human mind. The reply of the juſtly celebrated penſionary De Witt was much more judicious, and ought to be impreſſed on the mind of all young perſons. On being aſked how he contrived to tranſact ſuch a multiplicity of buſineſs in the courſe of a day without neglect or diſorder, he anſwered, "I make it a rule always to attend to one object at a time."

inſtinctive principles; but if I was diſpoſed to enter into the diſpute, this would not be the proper place.

The ſenſes are five in number: touch, taſte, ſmelling, hearing, and ſight. Of theſe I ſhall endeavour briefly to treat in their order. I have in general conſidered it as more conducive to perſpicuity, to ſeparate the anatomical deſcription of the organs from the functions to which they are ſubſervient; but as the organs of ſenſation are ſmall, and at the ſame time not much connected with the great outlines in the ſtructure of the body; and as the organs of ſome of the ſenſes, particularly that of hearing, are complex, and very difficult to be retained in the mind, I have, in this inſtance, thought it neceſſary to depart from the former arrangement.

CHAP. XXXVII.

TOUCH, AND ITS ORGANS.

The most extensive of the Senses.—Organs of Touch.—In what Manner it enables us to judge of the Qualities of Bodies.—Young Man couched by Cheselden.—Remarks on his Case.

IN order to protect the body from injury, almost every part of it is so formed as to give warning to the mind when any thing injurious assails it. The whole body may therefore, in the most extensive sense of the word, be deemed an organ of touch. The internal parts of the body, however, though they are capable of feeling, yet convey no other idea but that of pain, and give us no information with respect to the nature of what is applied to them. The surface of the body is endued with a much more extensive power, and informs us of several qualities of matter; but the lips, the tongue, and, above all, the fingers, afford us the most accurate information of those qualities of bodies which are the objects of this sense.

When the epidermis is removed from the true skin, we observe small obtuse papillæ, which seem to be the parts which more particularly receive the impressions of external objects. These papillæ are somewhat more remarkable in the skin at the ends of the fingers, and here we may perceive, that they have nerves, though from the extreme minuteness of them they are hardly observable. We judge of heat and cold from the object being hotter or colder than our fingers *; of the weight of a body, from its degree

* The tongue is a more nice test of the warmth of a body than the fingers, for we can feel a warmth at the larger end of an egg with the tongue, which is not perceptible by the fingers.

of preffure compared with its bulk; of its moifture, by its coldnefs, or the prefence of water; of its foftnefs, by its yielding; of its hardnefs, by the yielding of the finger; of its figure, by applying our hands to its different parts; of diftance, by comparifon with what we know to be the length of the finger, hand, or arm. All our conclufions, however, are fo regulated by previous experience, and we fo feldom truft to the evidence of touch without alfo calling in the affiftance of vifion, that without the latter fenfe the conclufions drawn from the other would be very limited and imperfect. Touch is the fenfe by which we acquire a knowledge of the diftance of objects, which, independent of experience, obtained by means of this fenfe, is not to be difcovered by vifion. This circumftance was beautifully illuftrated in the cafe of a young man, as ftated in Chefelden's anatomy. This young man, born blind, and being fuddenly enabled to fee, in confequence of a furgical operation, imagined that every thing he faw touched his eyes, and it was only by repeated trials of the diftance of objects, by means of touch, that he was taught to correct his error.

From this fact, however, it is not perfectly evident, that an infant, born with all its fenfes perfect, would naturally conclude that the objects of vifion touched its eyes. Might not the young man, from being fo accuftomed to judge of objects by their feel, or by applying them to his tongue or nofe, have acquired the idea, that nothing could be perceived which was not in contact with the body? and thus the conclufion which he drew might really depend on the affociation of ideas.

Chap. XXXVIII.

TASTE, AND ITS ORGANS.

The Tongue the Organ of Taste.—Description of it.—How supplied with Nerves.—Muscles of the Tongue.—How Tasting is performed.

THE tongue has been already casually mentioned as in some respects a very accurate organ of touch; but the sense to which it is more particularly subservient is that of taste. The palate is commonly considered as the organ of taste; but this is a vulgar error, for unless the substance applied to the palate has some degree of acrimony, no sensation whatever is the consequence. The tongue, and more particularly at the point, and the superior and the lateral parts of it, is the true organ of taste. The skin, with which the tongue is covered, is remarkably soft and thin, and is continually preserved moist and warm. On the surface of this skin papillæ, much larger than in any other part of the body, and of several sorts, are observable. The first kind are few in number, and are placed at the back part of the tongue. These are surrounded with a small furrow, and their form is almost that of an inverted cone. They are not of a very delicate structure, nor are they much concerned in tasting. The second kind, which are smaller and softer than the preceding, and into which the first gradually degenerate, have somewhat of the form of a mushroom; they are scattered on the superior surface of the tongue, till, becoming more numerous towards its sides, they are there distributed in diverging lines. The third kind are of a conical form, are mixed with the other kinds, and are very generally distributed

over the whole ſuperior part and ſides of the tongue. They are endued with a very acute power of ſenſation, and are the true organs of taſte. Theſe conical papillæ differ greatly in their ſize; and ſome of them are extremely minute. On an accurate examination we alſo find ſome filiform papillæ placed in the interſtices of the conical.

Theſe papillæ, beſides being copiouſly ſupplied with blood, are alſo furniſhed with nerves, of which the tongue receives more, in proportion to its bulk, than perhaps any other part of the body. The exhaling arteries, which are numerouſly diſtributed on the ſurface of the tongue, have no further concern in the ſenſe of taſting, than as they help to moiſten and keep the papillæ in a fit ſtate to perform their office. On the upper, and towards the back part of the tongue, are two or three openings, which pour out a mucous fluid. The papillæ in man are covered with a thin and ſemi-pellucid membrane, which anſwers the purpoſe of an epidermis. In many animals, as thoſe which feed on graſs, the tongue is covered with a very rough and thick membrane, perforated ſo as to admit the diſſolved food to the papillæ, which are placed beneath it.

Under the papillæ is placed the muſcular ſubſtance of the tongue. The muſcles, which conſtitute this ſubſtance, are ſo numerous, and are ſo confounded with each other and with the fat, that the moſt diligent anatomiſt is unable to trace the courſe of many of them. By the help of theſe muſcles the tongue is moveable in all directions, and may be rendered broad, narrow, or hollow, at pleaſure. The tongue is very plentifully ſupplied with blood-veſſels.

A circumſtance univerſally neceſſary to a body being taſted is, that it ſhould be diſſolved in the ſaliva, and in that ſtate applied to the papillæ.

CHAP. XXXIX.

SMELLING, AND ITS ORGANS.

Final Cauſe of this Senſe.—Leſs acute in Man than in ſome other Animals.—Different alſo from theirs.—Deſcription of the Organs of Scent.—Compariſon between this Senſe and that of Taſte.

AS the principal uſe of the organs of ſmelling is to aſſiſt animals in obtaining proper food, and to guard them againſt what is improper, they are univerſally placed near the mouth. The organs of ſmell differ, like thoſe of the other ſenſes, according to the deſtination of the animals to which they belong. This ſenſe in man is far leſs acute than that of many other animals; thus, the dog poſſeſſes a power of ſmelling, of which we can ſcarcely form a conception, and which we happily do not poſſeſs. Birds of prey, however, are ſaid to have the ſenſe of ſmelling ſtill more acute than dogs. The ſenſe of ſmelling in man is ſuch as to fit him for deriving enjoyment from a diverſity of ſcents, particularly thoſe of flowers, to which dogs and other animals, which do not feed on herbs, ſeem perfectly inſenſible.

The organ of ſmell is a ſoft, vaſcular, porous membrane, furniſhed with papillæ, which is ſpread on the internal ſurface of the noſtrils. On this membrane are diſtributed a great number of nervous fibres, which proceed chiefly from the firſt pair of nerves, and which paſs through the ethmoid bone. From the extreme tenuity of the epidermis, which involves the nerves and blood-veſſels in this membrane, he-

morrhage from the nose is more frequent than from any other part of the body.

In order to render this sense more acute, the internal cavity of the nose is variously contorted, and enlarged by a communication with several adjoining cavities, so as to increase very much the surface on which the sentient membrane is distributed. The cavities with which the nostril communicates are called sinuses; these are the frontal, which is seated in the frontal bone under the eye-brows; the ethmoid, which is a spongy cavity in the ethmoid bone; and the maxillary, which is chiefly formed in the maxillary bone, and lies immediately above the double teeth of the upper jaw. In animals, which smell more acutely, these provisions for enlarging the internal surface of the nostril are still more remarkable.

The membrane of the nose is defended and moistened by a viscid mucus; and so necessary is this to smelling, that when it is deficient, this sense is always imperfect. The nostrils are furnished with muscles, by which they are dilated, when, in order to distinguish scents more accurately, we draw in a large quantity of air. A considerable difference between smelling and tasting is, that the former is only acted on by the invisible effluvia of bodies which float in the air, the latter, by matter more condensed and visible. There seems, however, to be a greater similitude between tasting and smelling than between any two of the other senses; and when either of them is injured the other commonly suffers with it.

CHAP. XL.

HEARING, AND ITS ORGANS.

Description of the Ear.—Admirable Structure of this Organ for conveying and echoing Sound.—Ears of different Animals.—Manner in which the Pulses of Air are conveyed to the Ear.—Communication by the Eustachian Tube.—Reason why Persons who listen attentively open their Mouths.—The Membrana Tympani probably the great Instrument of hearing.

AS by the sense of smelling we distinguish certain particles floating in the air, so by that of hearing we discover the motions and vibrations of the air itself. The parts of the ear are distinguished into external and internal. The former of these divisions comprehends all those parts which we are able to observe without dissection, and which are separated from those of the internal ear by the membrana tympani, improperly called the drum of the ear, as it is only a membrane stretched before the entrance of the cavity which is properly the ear. The external ear, which from its resemblance to a certain sea-shell is called *concha*, is a cartilaginous funnel of an irregular oval form, moveably connected to the head by ligaments, muscles, and cellular substance. The muscles with which the ear is furnished, and which are much employed by quadrupeds, are of little or no use to man.

Different parts of the external ear are known by different names; its upper cartilaginous part is called the *ala* or wing, to distinguish it from the soft and pendent part below, called the lobe; its outer border or circle is called the *helix*, and the semicircle

within this, the *antihelix*. The moveable cartilage, placed immediately before the opening of the ear, is named the *tragus*, and an eminence oppofite to this, at the extremity of the *antihelix*, is called the *antitragus*. The concha, becoming narrower, terminates in the *meatus auditorius externus*, the external auditory canal. Into this are continued the cutis and epidermis, which, as they enter it, become much thinner and more fenfible, and are furnifhed with minute hairs, by which warning is given when any infect has found admittance, or when any injurious fubftance requires to be removed. This paffage, and the membrana tympani, by which it is terminated, are moiftened by a vifcid fecretion called the wax, which by ftagnation becomes hard, and, when neglected, fometimes accumulates to fuch a degree as to occafion deafnefs. If we were to examine all nature for a contrivance proper for augmenting and echoing founds with the utmoft force and the greateft exactnefs, we fhould find the ear beft formed for thefe purpofes; by its admirable ftructure it receives founds of all kinds, admits the greateft quantity in the fmalleft fpace, and echoes each back without confufion.

The external ear in different quadrupeds is differently framed, but always adapted to the creature's manner of life. In fhape it commonly refembles the oblique fection of a cone from near the apex to the bafis. Hares, and fuch other animals as are daily expofed to injuries from beafts of prey, have large ears directed backwards, their eye warning them of any danger before; rapacious animals, on the other hand, have their ears placed directly forwards, as we fee in the lion, cat, &c. The flow hounds, and other animals that are defigned to hear moft diftinctly the founds coming from below, have their ears hanging down-

wards, or their ears are flexible, becauſe they move their head for the moſt part with greater difficulty than man. Man again, who muſt equally hear ſounds coming from all quarters, but eſpecially ſuch as are ſent from about his own height, has his external ear placed in a vertical manner, ſomewhat turned forward. In ſhort, wherever we ſee a peculiarity in the make of this organ in any creature, we ſhall, with very little reflection, diſcover this form to be more convenient for that creature than another. The animal alſo has the power of directing the cone of the ear to the ſonorous body without moving the head *.

The membrana tympani is a membrane conſiſting of ſeveral laminæ. Externally there is the epidermis, under this the vaſcular cutis, and, laſtly, a dry, elaſtic, ſhining, and pellucid ſubſtance. Theſe laminæ are connected by their cellular ſubſtance. The membrana tympani is never naturally perforated, and the paſſage of ſmoke from the mouth through the external ear, mentioned by ſome authors †, is fabulous, except, perhaps, in ſome caſes, where a perforation had been accidentally made by violence or diſeaſe. By the action of particular muſcles, the membrana tympani is preſerved in a degree of tenſion fit for receiving the impreſſions of the air. Under it runs a branch of the fifth pair of nerves, called the chorda tympani.

The membrana tympani is ſtretched before a roundiſh cavity of the os petroſum, hence called the tympanum or drum, and which is about ſeven or eight lines wide, and half as many in depth. This cavity is increaſed in the adult by a communication with the cells of the maſtoid proceſs, which do not exiſt in the fœtus. Within, the tympanum is lined by a moiſt and

* Monro on Comparative Anatomy.

† By Dr. Goldſmith in particular.

vaſcular

vascular membrane. The tympanum communicates with the cavity of the fauces, by means of the meatus auditorius internus, or Eustachian tube. This canal, which is partly bony and partly cartilaginous, begins by a very narrow opening at the anterior and almost superior part of the tympanum, increasing in size as it advances towards the cavity of the fauces, where it terminates by an oval opening behind the nostrils.

Within the tympanum are lodged the little bones of the ear, which are four in number, and from their form have received the following names. 1. The malleus or hammer. 2. The incus or anvil. 3. The roundish or oval bone. 4. The stapes or stirrup.

The body of the malleus is placed in the upper part of the tympanum, and a long process, called the handle, descends between the laminæ of the membrana tympani, where it is accurately fixed. It is articulated with the incus by means of two projecting ridges and a furrow between them.

The incus, which consists of a body and two legs, and is not unlike a tooth with a double root, exceeds the other little bones of the ear in size and strength. Its body is connected with the malleus; its shorter leg is placed at the entrance of the canal, which leads to the cells of the mastoid process; its longer leg takes the same direction with the handle of the malleus, to which it is attached by a ligament, and being bent inwards at its termination, receives the small oval bone, and by means of this is united to the stapes.

The resemblance of the stapes to a stirrup is so strong, that it can scarcely escape observation. Its head, which is formed by the union of its two legs, is hollowed for the reception of the little oval bone which connects it with the longer leg of the incus. The two

legs

legs of the ſtapes are bent nearly into a circle, and where they unite at the baſis, cover the feneſtra ovalis. The ſtapes is ſituated in a part of the tympanum, ſeparated from the other parts by a particular membrane.

The ſtapes and malleus are each of them furniſhed with a little muſcle, called, from the bones to which they belong, ſtapedius and tenſor tympani. The firſt of theſe, which is the ſmalleſt diſtinct muſcle in the body, ariſes from a little cavity at the poſterior and upper part of the cavity of the tympanum, and its tendon is inſerted at the back part of the head of the ſtapes. This muſcle, which draws the ſtapes obliquely upwards, aſſiſts in ſtretching the membrana tympani. The other muſcle is more remarkable, and as it operates like the former in ſtretching the membrana tympani, has more particularly obtained the name of tenſor tympani. It ariſes from the cartilaginous extremity of the Euſtachian tube, and is inſerted into the back part of the handle of the malleus, which it helps to pull inwards, and by that means to ſtretch the membrana tympani.

That part of the ear which is ſituated behind the tympanum is called the labyrinth. The labyrinth is ſeparated from the tympanum by a bony partition, and only communicates with it by means of two openings of nearly equal ſize, one of which is the feneſtra ovalis, which is ſhut by the baſe of the ſtapes, the other the feneſtra rotunda, which is cloſed by a continuation of the membrane which lines the cavity of the tympanum.

In the labyrinth of the ear are ſituated the veſtibule, the three ſemi-circular canals, and the cochlea.

The veſtibule or porch is a cavity of an irregular roundiſh form, and is placed nearly in the center of the

the os petrosum, between the tympanum, the semicircular canals, and the cochlea. It is open on the side of the tympanum by means of the fenestra ovalis, and communicates with the upper portion of the cochlea by an oblong foramen, which is under the fenestra ovalis, from which it is separated only by a very thin partition.

The semicircular canals in the infant are formed of a distinct bony shell, but in the adult coalesce with the firm os petrosum, and are three in number. They form rather more than semicircles, and open at both ends into the vestibule. Only five openings, however, are observed, since two of the canals are united at one termination.

The cochlea, so called from its resemblance to the shell of a snail, is formed by a conical nucleus and circumvolutions of thin bony lamellæ, which perform two complete circles and an half before they terminate at the apex. The canal of the cochlea is divided by a septum into two parts, which are called the scalæ; of these one begins from the fenestra rotunda, and is called the scala tympani, the other from the vestibule, and is called the scala vestibuli. The septum, which divides the scalæ from each other, is partly bony and partly membranous; it is deficient at the apex of the cochlea, where the cavities of the scalæ communicate. The bony lamella which separates the two canals is exceedingly thin, and fills about two-thirds of the diameter of the canal. The rest of the septum is composed of a most delicate membrane, which lines the whole internal surface of the cochlea. The portio mollis of the seventh pair of nerves, furnishes a film of medullary matter to the whole internal surface of the vestibule, the semicircular canals, and the cochlea. Every part of the labyrinth is also supplied

with an aqueous exudation, which is ſuppoſed to receive and propagate to the nerves the vibratory motions imparted by the air. When this fluid is collected in too great quantity, or is compreſſed by the ſtapes, it is ſuppoſed to eſcape through two minute canals or aqueducts, lately deſcribed by Dr. Cotunni, a phyſician of Naples. One of the aqueducts opens into the bottom of the veſtibulum, and the other into the cochlea, near the feneſtra rotunda. They both paſs through the os petroſum, and communicate with the cranium; they are lined with a membrane, which is ſuppoſed to be a production of the dura mater.

The manner in which ſound is propagated by pulſes or undulations of the air has been fully, and, I truſt, clearly explained in a preceding part of this work *; and from what has been now ſtated it will appear, that the ear is an organ admirably adapted for the reception of theſe impreſſions. Sound is, however, not merely conveyed by the external cavity of the ear; but by means of the Euſtachian tube, the air finds admittance to the cavity of the tympanum, and the effect of the vibrating air, entering the mouth, may be conveyed to the ear. Hence we perceive the reaſon why perſons who liſten very attentively, and perſons affected with partial deafneſs, open their mouths. When we breathe, the air received by this paſſage preſſes the membrana tympani outwards, and when we make a very full inſpiration, as in yawning, this happens to ſuch a degree as to prevent the impreſſion of ſounds from without, and occaſions a temporary deafneſs.

Notwithſtanding the labour of anatomiſts in tracing the intricate, ſingular, and very curious ſtructure of

* See book v. chap. 10.

the ear, they have never been able to diſcover the peculiar uſes to which all the ſeveral parts are ſubſervient. That the concha is deſigned to catch and reverberate to the auditory tube the vibrations of the air we are certain, from the analogous effect of a ſimilar organ, the ear-trumpet. The membrana tympani, and the little bones of the ear, are ſaid to have been deſtroyed by diſeaſe, without depriving the patient of hearing. I cannot, however, ſuppoſe, that any part of the ear is unneceſſary. It therefore ſeems reaſonable to believe, that the membrana tympani, which is ſtretched acroſs the paſſage to which the vibrations of the air are directed, is deſigned to receive them, for which uſe, by its elaſtic nature, it is admirably fitted. The malleus is attached to the membrana tympani, the incus to the malleus; the oval bone connects one leg of the incus to the head of the ſtapes, and the baſis of the latter bone preſſes on the feneſtra ovalis. From this ſtructure we can ſcarely draw any other concluſion, than that the tremulous motion excited in the membrana tympani by the impreſſions of the air are propagated through the contents of the tympanum, and imparted to thoſe of the labyrinth, which are lined with a delicate nervous film, on which they may operate ſo as to produce the ideas of ſound. When, however, we contemplate the various parts of the labyrinth, we cannot aſſign any reaſon for ſo complex a ſtructure, and can only admire it as one of the wonders of creation. The analogy of other animals, indeed, inſtructs us in one particular, viz. that the cochlea is not eſſential to hearing, ſince birds and fiſh hear accurately without this part; but why it is not eſſential remains ſtill a queſtion.

To confeſs, however, that we are ignorant of the means by which we perceive ſounds, is not more humble

humble than we muſt alſo be with reſpect to the information derived from the other ſenſes. Why a particular object affects our ſenſes in a particular manner, is concealed from us by circumſtances which our underſtandings cannot diſcover. As objects appear green when ſeen through a green glaſs, ſo is every object modified by the medium of the ſenſes.

It is natural, however, to the human mind, to be deſirous of perceiving things as they really are, and this may be an enjoyment provided for us in a future ſtate, when we may regard the earth merely as a planet, and the ſun as a fixed ſtar; and when the mind, liberated from the fetters of the body, and endued with new faculties, may at once contract its attention to the laws which regulate the exiſtence of the minuteſt animal, and extend its views to the comprehenſion of all the vaſt bodies which conſtitute the ſolar ſyſtem.

CHAP. XLI.

SIGHT.

Description of the Eye.—Eyes of different Animals.—How Vision is performed.—How all the Parts of an Object are comprehended by the Eye.—An Image of every Object painted on the Retina of each Eye, and yet only one Object perceived.—Cause and Cure of squinting.—The Sense of Sight limited.—By what Means we judge of Distance.—State of the Sight at different Ages.—Cautions for preserving the Sight.

THE eyes, those exquisite organs which raise the perceptive powers of the mind to some comparison with those of superior beings, and which in an instant of time admit impressions from an almost infinite variety of objects, are in their structure extremely simple. They are situated in two cavities, the orbits, which afford them protection from a great variety of external injuries, and contain a quantity of fat, which answers the purpose of a soft cushion, on which they may rest, and perform their different motions with ease and safety. The globe of the eye is immediately covered by the eyelids, which are continuations of the common integuments of the body, doubled inwards, and attached to the eye, by which they produce what is called the tunica conjunctiva. Where the two eyelids are united together, they form the canthi, or angles of the eyes; that next the nose is called the internal large or inferior angle; the other, on the contrary, which is next the temples, is called the external small or superior angle. The edges of both eyelids are furnished with rims of cartilage called the tarsi; on the margins of these, which are called ciliary edges, are situated sebacious glands, which discharge an oily fluid for the purpose of preventing adhesion. The

ciliary edges of the tarsi are furnished with eye-lashes. The chief use of these seems to be, to prevent dust, and other matters floating in the atmosphere, from falling into the eyes.

At the internal angle of the eye is situated the caruncula lachrymalis, which is a small reddish oblong body. This substance seems to be glandular. By the aid of a microscope we observe upon it a great number of small hairs, covered by an oily yellowish matter. On the globe of the eye, near this glandular body, is a semilunar fold formed by the membrana conjunctiva. This fold, which is called the membrana semilunaris, is shaped like a crescent, the two points of which answer to the puncta lachrymalia, which are the beginnings of a canal terminating in the cavity of the nostrils.

The surface of the eye is constantly moistened by a very fine limpid fluid, the tears, which are chiefly, and perhaps wholly, derived from a gland, situated in a small depression of the os frontis, near the external angle of the eye. Its excretory ducts pierce the tunica conjunctiva just above the cartilaginous borders of the upper eyelids. As this fluid enters the eye at the superior angle, it naturally descends towards the inferior, and is also frequently spread over the surface of the eye by the motion of the eyelids. When it arrives, after thus having washed the eye, at the internal angle, it is conducted by the membrana semilunaris into the puncta lachrymalia, which lead into the sacchus lachrymalis, from which it is ultimately discharged into the nose.

When the eye is irritated by any extraneous substance, the tears are discharged in greater quantity, and thus serve as a defence to this tender organ, and sometimes wash away the cause of irritation, or facilitate its

removal. Affections of the mind alfo fometimes occafion an increafed flow of tears; the efficient caufe of this connection we cannot trace, but the final caufe feems to be to excite fympathy, and urge the unfeeling heart to acts of mercy and benevolence.

The ball of the eye is a cafe of a globular form. It confifts of three coats, an external one called the fclerotica, which is white and gliftening like the tendon of a mufcle; an intermediate one, abounding with blood-veffels, called the choroides; and an internal coat, called the retina, which is an extremely tender film or network, formed by the expanfion of the optic nerve. This defcription, however, applies only to the pofterior and lateral parts of the eye, for at the fore part of the eye, inftead of the opake tunica fclerotica, we obferve a projecting tranfparent circular part, continued from the fclerotica, which from its fubftance being tranfparent like horn, is called the cornea. This portion is fomewhat more convex than the fclerotica, and reprefents the fegment of a fmall fphere added to the fegment of a greater, or, to exprefs the fame idea in more familiar language, it may be confidered as refembling a convex watch-glafs, fixed on the lefs convex furface of a watch cafe.

The tunica choroides extends from the back part of the eye as far as the termination of the fclerotica, where it is firmly connected by means of a white ring projecting inwards, and called the ciliary circle or ligament. From this edge proceeds a very fine weblike membrane or curtain, called the iris. Its difference of colour in different perfons is a matter of common obfervation. In the middle of the iris is an opening which always appears black, and which is rendered narrower or wider by the contractile powers of the iris. This opening is called the pupil, through which the

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rays of light are admitted to the internal parts of the eye.

The tunica choroides is defcribed by fome authors as confifting of two laminæ. This defcription, however, applies much better to the eyes of fome animals, particularly to thofe of fheep, than to thofe of man. Thofe who fuppofe the choroides to confift of two laminæ, defcribe the external one as terminating at the ciliary ligament, and the internal one as extending further to form the iris. This iris itfelf is defcribed as confifting of two laminæ, and it is very certain that two fets of fibres may be obferved. Thefe are fuppofed to be mufcular, and from the mobility of the iris there feems no reafon to doubt of their being really fo. Some of the fibres are orbicular, and lie round the pupil; others are ftrait, and extend from the circumference of the iris to its center. The iris has motions of fuch a nature, that the pupil is contracted on the approach of a ftrong light, and is dilated in proportion as the light is lefs vivid. By this admirable yet fimple contrivance, the eye adapts itfelf to the different proportions of light to which it is expofed. If the pupil was always as much contracted as it is when expofed to the light of noon day, a weaker light, fuch as that of the moon, could not be admitted with fufficient freedom to anfwer any ufeful purpofe. On the contrary, if the pupil was immoveably dilated, we might take advantage of the fcattered rays of light, but fhould be diftreffed and blinded by the glorious effulgence of the mid-day fun. When a ftrong light fucceeds to darknefs, we are under a neceffity of clofing the eye-lids, or of turning away the head, till the pupil has been accommodated to the change by the contractile powers of the iris.

The choroid coat is internally covered with a flimy

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ſubſtance of a dark colour, called the pigmentum nigrum. The epithet black, however, is not deſcriptive of this ſubſtance in every race of animals. On the contrary, in the ferret the pigmentum is white, and this circumſtance enables that animal to ſee in the dark, a faculty well adapted to its habits and mode of life. In man, diſtinct viſion in a full light is a more uſeful quality than the power of diſtinguiſhing objects where the light of day is excluded. The reaſon, therefore, of the black colour of the pigmentum is, probably, that thoſe rays which paſs the retina, which is a fibrous ſubſtance, may be abſorbed, whereas, when it is of a light colour, many of them are reflected and ſtrike the retina, thus increaſing the power of viſion where there is a deficiency of light, but producing too great an effulgence and glare in ordinary caſes. This reflection is very obvious in the degree of illumination which proceeds from the eyes of a cat in a dark place *.

The poſterior part of the iris is of the colour of a grape, and was therefore by the ancients called the uvea. The eye, being, therefore, every where provided within, except at the entrance of the optic nerve, with a lining of a dark colour, becomes a camera obſcura, and the light which is admitted through the pupil, and paſſes to the bottom of the eye, is not diſturbed with light reflected from other ſurfaces.

The ball of the eye is filled with three ſubſtances, which differ from each other in conſiſtence, but are all called humours of the eye; they are the vitreous, the cryſtalline, and the aqueous. See plate xv. fig. 1, and 2.

* Hunter on the pigmentum of the eye. See his Animal Economy.

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The vitreous humour was ſo called from a ſuppoſed reſemblance to melted glaſs; it is a clear and gelatinous fluid, very much reſembling the white of an egg. It fills about three fourths of the globe of the eye, and extends from the poſterior part of the eye as far as the ciliary ligament. It is contained in a fine tranſparent capſule or membrane, and being dexterouſly removed from the globe of the eye, preſerves its conſiſtence for ſome time, being ſupported by its capſule, but afterwards runs off, and the capſule ſhrinks by degrees. The thin capſule which ſurrounds the vitreous humour ſends off a number of membraneous proceſſes into the vitreous ſubſtance, where they form cells, which communicate with each other, and afford a greater degree of firmneſs and tenacity to the whole maſs.

The anterior part of the vitreous humour is excavated for the reception of the cryſtalline. This body has the conſiſtence of very firm jelly, and has the form of a lens more convex behind than before. It is moſt properly denominated the cryſtalline lens, and is inveſted with a capſule, which is derived from that of the vitreous humour, or at leaſt connected with it. Steno obſerved, that the lens was compoſed of concentric lamellæ, and Zinn has diſcovered radiated ſtreaks of a pearl colour, dividing it into little triangles. The colour and conſiſtence of the cryſtalline humour varies at different ages. Till the age of thirty it is very tranſparent, and almoſt without any colour. It afterwards becomes yellowiſh, and that yellowneſs gradually increaſes. Till the age of twenty the conſiſtence of the lens is generally uniform throughout; from this time it becomes hardeſt in the middle, and this hardneſs gradually increaſes, and extends towards the ſurface *.

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* The cryſtalline lens in fiſh is completely ſpherical, and is more denſe than in terreſtrial animals. This difference is to be

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The fore part of the eye is filled by a fluid tranſparent like the others, but as thin as water, and it is therefore called aqueous; this occupies all the ſpace between the cryſtalline lens and the prominent cornea. The iris floats looſely in this fluid, and divides it into two parts called chambers, which communicate with each other through the pupil. The poſterior chamber is that ſpace contained between the poſterior ſurface of the iris and the lens; the anterior is that between the anterior part of the iris and the cornea.

The eye receives its blood from the internal carotid artery. The optic nerve does not enter it immediately behind the pupil at its poſterior part, but rather towards the noſe, ſo that the diſtance between the pupil and optic nerve is greater when meaſured round the external ſide of the eye next the forehead, than when the internal ſurface is meaſured next the noſe. At that part of the eye where the optic nerve enters, no ſenſe of viſion can be excited.

The muſcles of the eye have been already deſcribed in another part of the work. For the human eye, ſee Plate XV. Fig. 1, and 2.

The father of the preſent Dr. Monro, of Edinburgh, has publiſhed, in his comparative anatomy, ſome excellent remarks on the variety in the eyes of different animals, than which no more ſtriking inſtance can be produced of the wiſdom and deſign which pervades creation.

' All quadrupeds have, he obſerves, at the internal canthus of the eye, a ſtrong firm membrane with a

accounted for from the different refractive power of the medium in which they live. The rays of light, in paſſing out of one medium into another, undergo a refraction proportioned to the difference of their denſities. As water, therefore, is a more denſe medium than air, the eyes of ſuch animals as inhabit the former muſt have a greater refractive power than thoſe which live in the latter, for the production of diſtinct viſion.

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cartilaginous edge, which may be made to cover ſome part of their eye; and this is greater or leſs in different animals, as their eyes are more or leſs expoſed to dangers in ſearching after their food. This *membrana nictitans*, as it is called, is however not very large in all theſe animals. Cows and horſes have it ſo large as to cover one half of the eye like a curtain, and at the ſame time it is tranſparent enough to allow abundance of the rays of light to paſs through it. Fiſhes have a cuticle always over their eyes, as they are ever in danger in that inconſtant element, the water. In this therefore we may obſerve a ſort of gradation.

'All quadrupeds have a ſeventh muſcle belonging to the eye, called *ſuſpenſorius*. It ſurrounds almoſt the whole optic nerve, and is fixed into the ſclerotic coat as the others are. Its uſe is to ſuſtain the weight of the globe of the eye, and to prevent the optic nerve from being too much ſtretched, without obliging the four ſtrait muſcles to be in a continual contraction, which would be inconvenient: at the ſame time this muſcle may be brought to aſſiſt any of the other four, by cauſing one particular portion of it to act at a time.

'The next thing to be remarked is the figure of the pupil, which is different in different animals, but always exactly accommodated to the creature's way of life, as well as to the different ſpecies of objects that are viewed. Man has it circular, for obvious reaſons: an ox has it oval, with the longeſt diameter placed tranſverſely, to take in a larger view of its food: cats, again, have theirs likewiſe oval, but the longeſt diameter placed perpendicularly; they can either exclude a bright light altogether, or admit only as much as is neceſſary. The pupil of different animals varies in wideneſs, according as the internal organs of viſion are more or leſs acute: thus cats and owls, who ſeek their

prey in the night, or in dark places (and consequently must have their eyes so formed as that a few rays of light may make a lively impression on the retina), have their pupils in the day-time contracted into a very narrow space, as a great number of rays would oppress their nice organs; while in the night, or where the light is faint, they open the pupil, and very fully admit the rays. In the same way, when the retina is inflamed, a great number of rays of light would occasion a painful sensation; therefore the pupil is contracted: on the contrary, in dying people, or in a beginning amaurosis, it is generally dilated, as the eyes on such occasions are very difficultly affected, and in some measure insensible. See Plate XV. Fig. 3, 4, 5.

'The posterior part of the choroid coat, which is called tapetum, is of different colours in different creatures. For oxen, feeding mostly on grass, have this membrane of a green colour, that it may reflect upon the retina all the rays of light which come from the objects of that colour, while other rays are absorbed: thus the animal sees its food better than it does other objects. Cats and owls have their tapetum of a whitish colour; and for the same reasons have the pupil very dilatable, and their organs of vision acute: and we shall find, that all animals see more or less distinctly in the dark, according as their tapetum approaches nearer to white or black colour. Thus dogs, who have it of a greyish colour, distinguish objects better in the night than man, whose tapetum is dark brown, and who, I believe, sees worst in the dark of any creature; it being originally designed that he should rest from all kinds of employment in the night time. The difference then of the colour of the tapetum, as indeed the fabric of any other part in different creatures, always depends on some particular advantage accruing

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to the animal in its peculiar manner of life from this ſingularity *.'

It was neceſſary, in a former part of this work, to notice the ſubject of viſion, in deſcribing the effects and phenomena of light †. The eye was then mentioned as a mere optical inſtrument, but after the particular deſcription of that organ, which has now been given, a more particular inveſtigation of the ſenſe of ſight ſeems to be required; and ſhould the reader find any thing like repetition in what will now be ſubmitted to him, his candour will, I doubt not, pronounce my apology for endeavouring to render as clear as poſſible a ſubject which is at once both important and difficult to be underſtood.

It has been ſufficiently explained, that from every point of a viſible object the rays, or rather pencils, of light are emitted or reflected in every direction; but to produce viſion, it is neceſſary that they ſhould be concentrated or converged to a ſuch point as to make a forcible impreſſion on the retina. Thus from the luminous body A (Fig. 6.) the rays *r*, *r*, *r* are ſent in various directions. Thoſe which fall upon the tranſparent cornea C C are there refracted in ſuch a manner as to enter the pupil at *p*, and in paſſing the cryſtalline lens or humour they ſuffer a ſecond refraction, and are converged to a point or focus at the point *a* on the retina. Now it is evident, that if the rays could have paſſed the humours of the eye in their natural direction, that is in the direction of the cone or pyramid C, A, C, they would have made upon the retina a very extenſive but feeble impreſſion, ſuch as we know by experience could not produce diſtinct viſion; to obviate this

* Monro's Comparative Anatomy.
† See book iii. chap. 7.

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it is appointed by the all-wise author of our existence, that by the force of the refraction which they suffer in the eye, they should form another cone opposed to the first at its base, and the apex of which is at *a*, and thus an impression sufficiently forcible to produce distinct vision is made on the retina.

In the preceding instance, the luminous body A was considered as a point, and what has been said of it will apply to *every point* of a visible object, which is capable of transmitting or reflecting to the eye a pencil or collection of rays. Thus we may easily suppose that from every point of the arrow A, D, B, (Fig. 7.) pencils of light may be transmitted; these, like all pencils or collections of rays, coming from a point, will diverge, and will fall upon the eye in the form of cones or pyramids, such as A, M, C, from the point A; D, *e*, *i* from the point D; and B, C, N, from the point B. If the eye, therefore, is in a proper state, the divergent rays proceeding from the point D will be united together into one pencil or mass, such as they were when they first proceeded from the object, at the point *d*, upon the retina; the divergent rays, which fall more obliquely from the point A, will be united on the retina, at the point *a*; and those which proceeded from B will, by the same rule, be converged and meet at *b*. Hence it is evident, that by means of this refraction there are certain points at which the rays of light, after passing the pupil, cross each other, and the image which is formed on the retina is consequently inverted.

If the humours of the eye, through age or weakness, have shrunk or decayed, the cornea will then be too flat, and the rays not being sufficiently bent or refracted, arrive at the retina before they are united in a focus, and would meet, if not intercepted in some place behind

Fig. 1. Section of the Human Eye.

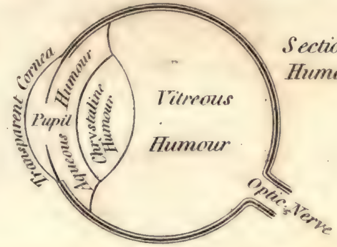


Fig. 2. Human Eye.

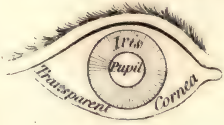


Fig. 3. Horse.

Fig. 4. Bird.

Fig. 5. Cat.

Fig. 6.

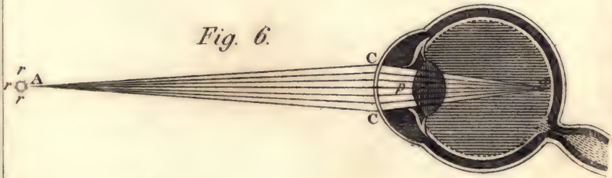
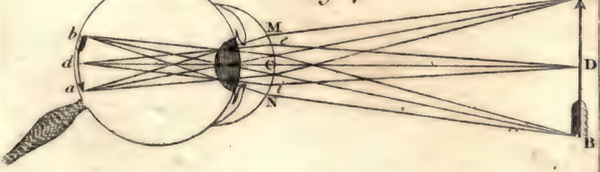


Fig. 7.



hind it, as in Plate XVI. Fig. 8. They therefore do not make an impreſſion ſufficiently correct and forcible, but form an indiſtinct picture on the bottom of the eye, and exhibit the object in a confuſed and imperfect manner. This defect of the eye is therefore remedied by a double convex lens, ſuch as the common ſpectacle glaſſes, which, by cauſing the rays to converge ſooner than they otherwiſe would, afford that aid to this defect of nature which the circumſtances of the caſe may require, the convexity of the glaſs being always proportioned to the deficiency in viſion.

If, on the contrary, the cornea is too convex, the rays will unite in a focus before their arrival at the retina, as in fig. 9, and the image will alſo be indiſtinct. This defect is remedied by concave glaſſes, which cauſe the rays to diverge, and conſequently, by being properly adapted to the caſe, will enable the eye to form the image in its proper place.

As the direction in which the rays croſs each other bears a due proportion to the angle in which they are tranſmitted from the object to the eye, it is evident that the image formed upon the retina will be proportioned to the apparent magnitude; and thus we have our firſt ideas of the ſize and diſtance of bodies, which, however, in many caſes are corrected by experience. The nearer any object is to the eye, the larger is the angle by which it will appear in the eye, and therefore the greater will be the ſeeming magnitude of that body. This fact has been already explained, but to render it ſtill clearer, ſuppoſe the object H K (ſee Fig. 10.) to be at a hundred yards diſtance, it will form an angle in the eye at A. At two hundred yards diſtance, the angle it makes will be twice as ſmall in the eye at B. Thus to whatever moderate diſtance the object is removed, the angle it forms in the eye will

will be proportionably less, and therefore the object will be diminished in the same proportion.

From some late experiments made by Dr. Hosach and Mr. Ramsden, it appears, that the power of changing the focus of the eye, and adapting it to different distances, does not reside in the crystalline lens, but in the cornea; that the cornea is composed of laminæ; that it is elastic, and capable of being elongated one eleventh of its diameter, and of contracting to its former length by its own exertions; and lastly, that the tendons of the four strait muscles of the eye are continued to the edge of the cornea, and terminate or are inserted in its external lamina. By the same experiments it was found, that in changing the focus of the eye from seeing with parallel rays to a near distance, there is a visible alteration produced in the figure of the cornea, which renders it more convex; and the alteration by which the cornea is brought back to its former state is equally visible *.

Artificial eyes are sold by the opticians, in which all the humours are made of different kinds of glass, and may be separated at pleasure. At the back part, where the retina is supposed in the natural eye to receive the converged rays, is placed a piece of ground glass, where the image from the opposed objects is painted in an inverted position, as in a camera obscura. The same effect may be produced with a natural eye, and the nature of vision may be thus experimentally demonstrated: if a bullock's eye is taken fresh, the posterior coats dexterously removed even to the vitreous humour, and if a piece of white paper is then placed at the part, the image of any bright object which is placed before the eye will be seen distinctly painted on the paper, but in an inverted position.

* Phil. Transf. for 1795, Part. 1.

Fig. 8.

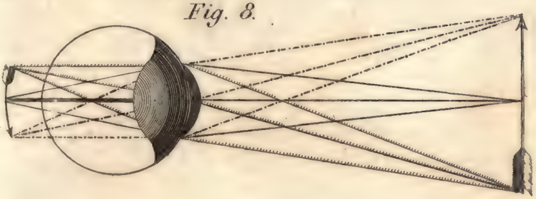


Fig. 9.

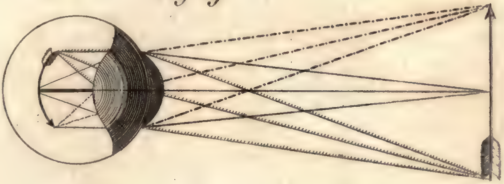


Fig. 11.

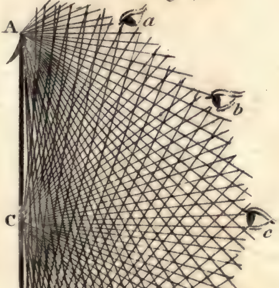


Fig. 10.

It has been a matter of much doubt and dispute by what means it happens that we see every object in its natural upright position, when we know it to be inverted on the object of sensation. To this the most satisfactory answer that can be given is, that we do not see the picture which is formed at the bottom of the eye, but the object itself. The picture, or rather the impression made on the retina, is the means of seeing, and therefore it does not appear of material consequence on what part of the retina the impression is made. We in fact see the image in the direction of that ray which conveys to us the sensation, or rather in the direction of the axis of that pyramid, which a pencil of divergent rays forms in proceeding from any point of an object. Thus in Fig. 7. we see the point of the arrow (which is indeed depicted in the lower part of the eye) in the direction of the line *a*, A, that is, in its proper upright position. On the contrary, we see the other extremity of the arrow (which is painted on the superior part of the retina) in the direction of *b*, B, that is at the lower end of the object. However, therefore, the image, which is formed, may appear inverted to a person inspecting a natural eye, as in the preceding experiment, still the eye itself discerns the object in its proper and natural position.

As the rays of light are emitted or reflected from a visible object in all directions, it is evident, that some of them from every part of it must reach the eye. Thus the object A, B, C. (Fig. 11.) is visible to an eye in any part, where the rays A *a*, A *b*, A *c*, A *d*, A *e*, B *a*, B *b*, B *c*, B *d*, B *e*, C *a*, C *b*, C *c*, C *d*, and C *e* can come. But though rays are reflected from every point of the object to every point of the circumambient space, yet it is evident, that only those rays which pass through the pupil of the eye can affect the

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sense; these rays give also the idea of different colours, according to the properties of the bodies which transmit or reflect them, upon the principles formerly demonstrated.

It is very difficult to explain how it happens that two distinct images are painted upon both eyes, and yet that we only perceive a single object. This difficulty has been attempted to be solved by having recourse to the power of habit; but I confess I cannot help being of opinion with Dr. Reid, that the correspondence of the centers of the two eyes, on which single vision depends, does not arise from custom, but from some natural constitution of the optic nerves. The case of the young man born blind, who was couched by Mr. Cheselden, and who saw singly with both eyes, immediately upon receiving his sight, is very properly adduced by that respectable author in favour of this supposition. He also found, that three young gentlemen, whom he endeavoured to cure of squinting, saw objects singly, as soon as they were brought to direct the centers of both eyes to the same object, though they had never been used to do so from their infancy; he remarks too, that there are cases in which the fullest conviction of an object being single will never make the object appear so, even by the longest practice, as in the case of looking through a multiplying glass *.

In those who squint, the distance between the two pupils is considerably less than in other persons, for when the pupil of the undistorted eye is seated in the middle of the orbit, as in looking directly forwards, the pupil of the other eye is drawn close to the nose, so that the two axes are never pointed at the same object,

* Reid's Inquiry into Human Mind, p. 267.

ject, though the muſcles ſo far act in concert with each other, as to move both eyes the ſame way at the ſame inſtant of time. Dr. Jurin obſerves, that this vicious habit may eaſily be contracted by a child, if he is laid in his cradle in ſuch a poſition as to perceive the light with one eye only.

The moſt common cauſe of ſquinting is, however, an inferiority in the ſight of one of the eyes. Dr. Reid aſſerts, that having examined above twenty perſons, who ſquinted, he found in all of them a defect in the ſight of one eye. Four of them only had ſo much of diſtinct viſion in the weak eye as to be able to read with it, while the other was covered; the reſt ſaw nothing diſtinctly with the defective eye *.

When the eyes are equally good, we ſee with both eyes more diſtinctly than with one, by about a thirteenth part; but when the eyes are unequal in their powers, objects appear leſs diſtinct with both eyes than with one. It is no wonder, therefore, that ſuch perſons ſhould chuſe to make uſe of one eye only, and to turn the other aſide; the weak eye, in this caſe, is generally turned to the noſe, becauſe in that ſituation the direction of its axis is as diſtant as poſſible from that of the good eye; and beſides this, the noſe conceals many objects from its view.

This is, however, not the only cauſe of ſquinting; it is ſometimes, though rarely, the effect of habit, as was intimated reſpecting children being laid in the cradle with one eye turned from the light, or covered. When the eye that ſquints is turned outwards towards the temples, that caſt of the eye is commonly the mere effect of habit.

If the eyes differ much in point of goodneſs, the cure will be extremely difficult. When they do not

* Reid's Inquiry into Human Mind, p. 253.

materially

materially differ in this respect, the proper and natural cure is to cover the good eye for some time; for in this case the distorted eye is obliged to act, and to turn itself directly to objects, which in a little time becomes natural and easy to it. Even a very weak eye acquires strength by exercise; persons whose squinting seemed almost incurable, having covered their good eye for a few minutes only, have been themselves surprised to find the strength that their bad eye had acquired by exercise even for that short period. When the squint has proceeded entirely from a vicious habit, a cure has been effected by covering the good eye for a fortnight only*.

The powers of this sense are limited, as well as those of every other sense and faculty of man.

1st. The sight is very limited with respect to bodies in motion; for with a certain degree of velocity, as that of a cannon ball through the air, they are not visible, unless very luminous.

2. The same effect is exemplified by the experiment of whirling a lighted coal, as was already intimated.

3. If two objects unequally distant move with the same degree of velocity, the more remote will appear the slower. 4th. A visible object moving with any velocity appears to be at rest, if the space described in a second of time is invisible to the eye. Thus a near object, as the index of a clock, moving slowly, or a remote one, as a planet, moving swiftly, appears to be at rest. 5th. It is well known, that when the eye is proceeding strait forward, as in a boat at sea, a lateral object, either at rest, or moving not so fast, appears to move the contrary way. 6th. If, however, the

* Reid's Inquiry into the Human Mind, p. 253.

the object is at a very great diſtance, it will ſeem to go the ſame way, as when a perſon runs by moonlight, the moon appears to accompany him. 7th. If two or more objects move with the ſame velocity, and a third remains at reſt, it will appear in motion while the moving ones ſeem at reſt; this is exemplified by the moon and the clouds.

There are ſix natural methods, by which we judge of the diſtance of objects from the eye. 1ſt. By the angle which is made by the optic axes. For want of this direction it has been obſerved, that perſons who are blind of one eye frequently miſs their mark in pouring liquor into a glaſs, &c. 2ndly, and I think moſt generally, by the apparent magnitude of objects. By depending upon this method we are very frequently deceived in our eſtimates of diſtance by any extraordinary large objects, as in travelling to a great city, church, or caſtle, we fancy them nearer than they really are. This furniſhes us with a reaſon why animals and other ſmall objects ſeen contiguous to large mountains appear exceedingly ſmall; for we imagine the mountain to be nearer to us than it actually is. When we look down alſo from a high building, the objects beneath us appear much ſmaller than they would at the ſame diſtance on the level ground; the reaſon is plainly, becauſe we have no diſtinct idea of diſtance in that direction, and therefore judge by the impreſſions upon the retina, whereas cuſtom has corrected our judgment in the other caſe. The third method of determining the diſtance of objects is by the force and vividneſs of the colours, and the fifth is analogous to it, namely, by the different appearance of the minute parts. When theſe appear diſtinct, we judge the object to be near, and the contrary when they appear

faint or confuſed. 6thly, We are aſſiſted in judging of the diſtance of any particular objects, by the other objects which are interpoſed. On this account, diſtances upon uneven ground do not appear ſo great as upon a plain; for the valleys, rivers, and other objects that lie low, are many of them loſt to the ſight. This too is the reaſon why the banks of a river appear contiguous when the river lies low and is not ſeen *.

In children the pupil is uſually more dilated than in grown perſons. The reaſon of this appears to be, that in childhood the cornea is more flexible, ſo as to be very eaſily bent into any curvature neceſſary for diſtinct viſion, and conſequently the pupil has leſs occaſion to contract. In grown perſons the cornea is ſtiffer, they have therefore more neceſſity to contract the pupil. In elderly perſons the cornea grows ſtill more rigid; for this reaſon they are obliged ſometimes to hold the candle between the eye and the paper on which they read; and their doing ſo is a direct indication that they begin to want ſpectacles †.

Children read much nearer than grown perſons, both becauſe their eyes are ſmaller, and becauſe their cornea is more flexible. That elderly perſons ſee better at a great diſtance than younger perſons is generally allowed.

It is a certain and very important fact, that long-ſightedneſs may be acquired, for countrymen, ſailors, and thoſe that are habituated to look at remote objects, are generally long-ſighted, want ſpectacles ſooneſt, and uſe the deepeſt magnifiers; on the other hand, the far greater part of the ſhort ſighted are to

* Eſſay on Viſion, quoted by Prieſtley.

† Porterfield on the Eye, quoted by Prieſt. Op. Per. 6. ſ. 12.

be found among ſtudents, and thoſe who are converſant with ſmall and near objects; every one becoming expert in that kind of viſion which is moſt uſeful to him in his particular profeſſion and manner of life.

Mr. Adams, in his very uſeful eſſay on viſion, has given ſome rules for the preſervation of the ſight, which, for the benefit of the ſtudious reader, I have thought it proper to inſert.

1ſt. Never ſit for any length of time in abſolute gloom, or expoſed to a blaze of light. From this rule may be deduced the impropriety of going haſtily from one extreme to the other, whether of darkneſs or of light, and it may be inferred that a ſouthern aſpect is improper for thoſe whoſe ſight is weak and tender. 2dly. Avoid reading a ſmall print. 3dly. Do not read in the duſk, nor, if the eyes are diſordered, by candle light. 4thly. The eye ſhould not be permitted to dwell on glaring objects, more particularly on the firſt waking in the morning. 5thly. The long ſighted ſhould accuſtom themſelves to read with rather leſs light, and ſomewhat nearer to the eye than uſual, while thoſe who are ſhort ſighted ſhould uſe themſelves to read with the book as far off as poſſible.

CHAP. XLII.

THE GESTATION AND BIRTH OF ANIMALS.

Varieties in the Production of Animals.—Proportion of Males to Females.—Growth of the Fœtus.—Oviparous Animals.—Mode of Existence before Birth.—Weight of a new born Infant.—Miscellaneous Calculations concerning the Proportion of Births to that of Deaths in Infancy, &c.

WE have hitherto been occupied in considering the functions which relate to the existence and welfare of animals, let us now direct our attention to those which, amidst the decay of individuals, preserve the continuance of the species.

Among the more minute and imperfect animals, there are some which may be multiplied from fragments of the same species, as the polypus; others grow from the bodies of their parents, and are in due season set at liberty to seek nourishment for themselves; some animals, at a certain period of their existence, naturally divide into several parts, each of which afterwards becomes a perfect animal of the same race.

As we ascend in the scale of animal existence, a difference of sex presents itself as a leading distinction. We find some races of animals, of which every individual is possessed of both male and female organs; others, among which a single female breeds for a whole community, and among which there are very few individuals possessed of sexual organs. In general, however, about half the individuals of a species are males and half females.

It

It is in ſome meaſure foreign to the objects of the preſent work to enter on thoſe theories with which philoſophers have amuſed themſelves and their readers concerning the generation of animals. Independent of the indelicacy of the ſubject, there is another ſtrong objection to their introduction here; ſince theſe theories reſt upon no other foundation than conjecture, and ſome fallacious, and, I think, deluſive microſcopical obſervations. I ſhall, therefore, content myſelf with referring the reader to the natural hiſtory of the Count de Buffon, and for a direct contradiction of his theory to the Abbe Spalanzani. The former of theſe philoſophers has derived the principle of animal exiſtence from the male, and the latter from the female. The generation of fiſhes appears, indeed, greatly to favour the theory of Spalanzani, for in that inſtance at leaſt, the rudiments of the young animals appear to be contained in the eggs or roe, which the female fiſh firſt depoſits; and the milt which is afterwards depoſited by the male appears only to excite them into action and growth. If we admit thus much of his theory, however, we muſt attend him a ſtep further, and ſuppoſe that every female ovum in the ovarium of a female muſt itſelf contain ovaria and ova, and by extending the ſame idea we muſt be led to conclude, that the rudiments of all the animals, which have exiſted, do exiſt, or ever will exiſt, were originally contained in the ovarium of the firſt female of the particular ſpecies to which they reſpectively belong. This has been therefore called the theory of involution, and has been ſuppoſed equally applicable to animals and vegetables.

In the proceſs of generation, the firſt marks we ſee, after impregnation, of the future progeny, is a minute being without limb or feature, connected by a cord to

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the internal ſurface of the uterus, and ſurrounded by very thin membranes. It ſeems formed, however, of two maſſes joined together, the larger of which is the head and the ſmaller the body. As the fœtus advances in growth the body acquires a larger ſize with reſpect to the head, ſmall protuberances make their appearance on the body, which are the future limbs, and the features begin to manifeſt themſelves. In this manner the fœtus, gradually acquiring a more determinate ſtructure, and more evident marks of the ſpecies to which it belongs, is at length diſengaged from the mother. In different ſpecies there is great variety in the perfection of the animal at the time of birth; the young of the human ſpecies is, perhaps, the moſt backward of any in this reſpect; for a child, when ſix months old, is not ſo able to provide for itſelf as a horſe or an aſs at the age of as many days.

In many races of animals, it ſhould be obſerved, particularly in birds, the growth of the fœtus takes place out of the body of the mother. This is indeed the caſe with all animals which ſpring from eggs, and in which we have a very favourable opportunity of obſerving the progreſs of the fœtus from its firſt appearance till it has acquired that ſtate of perfection at which it is hatched. During the whole period of its growth it is ſupported by a limited quantity of nouriſhment contained within the egg-ſhell, and which is that part of the egg called the yolk.

The human fœtus is ſurrounded with three membranes; the external of theſe is vaſcular, and is called the ſpongy chorion; the middle coat, called the media or true chorion, and the internal one, called the amnion, are not ſo. Mr. Hunter has found the ſpongy chorion to conſiſt of two layers; that which lines the uterus he calls *membrana caduca* or *decidua*, becauſe it

is caſt off after delivery; the portion which covers the ovum, *decidua reflexa*, becauſe it is reflected from the uterus upon the ovum. The membrana decidua is, according to Mr. Hunter, perforated with three foramina, viz. two ſmall foramina, correſponding to the openings of the Fallopian tubes at the fundus uteri, and a larger one oppoſite its cervix. The decidua reflexa becomes more thick and vaſcular as it approaches the placenta, and conſtitutes its maternal part.

The fœtus appears floating in a tranſparent fluid contained in the amnion, ſuſpended by the umbilical cord, and the head, being the largeſt part, and the inſertion of the umbilical cord being at a conſiderable diſtance from it, falls loweſt; a circumſtance very neceſſary to ſafe and eaſy delivery. The fœtus, when it has nearly obtained its growth, is curled up in an oval form; its back is round, and turned towards one ſide of the mother, making that ſide more protuberant; its chin is preſſed againſt its breaſt; with its arms it embraces its knees, and its heels are cloſe to its buttocks. A moſt curious but ſomewhat complicated branch of the animal œconomy, is the means which nature employs for carrying on the nouriſhment of the fœtus. I have already mentioned the umbilical cord, which connects the fœtus to the uterus. One end of this cord is connected to the ſubſtance called the placenta, and the other enters the navel of the fœtus. The placenta is a ſpongy ſubſtance as broad as the crown of a hat, and about two fingers in thickneſs, and is commonly attached to the upper part of the uterus. The outer ſurface of the placenta is ſoft, tender, and ſpongy, and commonly bloody, on account of its ſeparation from the veſſels of the uterus. Its internal ſurface, where it is covered by the membranes, is firm, gloſſy, and

beautifully marked with the ramifications of blood-veſſels. On the outſide the blood-veſſels can ſcarcely be obſerved, as they are there very minute. On the outſide of the placenta there is alſo an appearance like a diviſion into lobes. The umbilical cord is generally inſerted, not into the middle, but towards the edge of the placenta, which facilitates its ſeparation after delivery. With the placenta, as has been ſuppoſed, the arteries of the uterus have a communication, by which, in the firſt periods of geſtation, the fœtus receives a ſerous fluid, and in the later periods a large quantity of blood.

It has alſo been taken for granted, that the arteries of the umbilical cord communicate with the veins of the uterus, and that thus a circulation of fluids is maintained between the fœtus and the mother. Mr. Hunter, however, after numerous experiments, has adopted a different opinion. By a variety of trials by injection he finds, that fluids thrown into the veſſels of the umbilical cord never get into thoſe of the uterus; and on the contrary, thoſe thrown into the veſſels of the uterus find no admiſſion into thoſe of the umbilical cord; he therefore concludes, that the human placenta, as well as that of quadrupeds, is a compoſition of two parts intimately blended, viz. an umbilical or infantile portion, and an uterine portion. The former by maceration, is found to conſiſt of the ramifications of the veſſels of the umbilical cord, the other Mr. Hunter conſidered as an efflorefcence of the internal ſurface of the uterus, which forms a membrane, ſending numerous proceſſes into the ſubſtance of the placenta; this latter is the membrana decidua. Mr. Hunter does not pretend to ſpecify the nature of the union between theſe two portions of the placenta.

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The veins of the placenta unite into a ſingle trunk, which, leaving the placenta, enters the navel of the fœtus. Two arteries, which are continued from the internal iliac arteries, paſs out at the navel of the fœtus and enter the placenta; and theſe, with the vein above mentioned, conſtitute the umbilical cord. By means of theſe arteries and veins, a communication is maintained between the fœtus and the placenta. The umbilical veſſels do not run in a direct courſe, but both the arteries and the vein are mutually twiſted about each other. The umbilical cord paſſes from the fœtus to the placenta, through the *liquor amnii*. The winding courſe of theſe veſſels, and the elaſticity of the ſubſtance which ſurrounds them, protect them in a great meaſure from the bad effects which would otherwiſe happen, from their being ſtretched or preſſed, which might put a ſtop to the circulation. Beſides theſe veſſels, however, there is another in brutes, called the urachus, which conveys the urine from the bladder to a veſſel called the allantoides. In the human ſpecies, both the urachus and the allantoides are wanting.

There is, indeed, in the human fœtus, ſomething like an urachus, which goes from the bladder of the fœtus to the navel, between the umbilical arteries, but it ſeems to be of no uſe, as it does not communicate with the bladder.

The umbilical vein, after it has entered the body of the fœtus, divides into two branches, one of which enters the vena portarum to be diſtributed in the liver; the other, which is called the ductus venoſus, carries its contents to the left vena cava hepatis, which terminates in the great vena cava; and that part of the blood which paſſes through the liver alſo arrives at the vena cava. From the vena cava the blood paſſes into the

anterior

anterior auricle, whence there is a paſſage into the poſterior auricle, which is cloſed up after birth, but which now turns the greater part of the blood received by the anterior auricle, from the anterior to the poſterior cavities of the heart. A conſiderable quantity of blood, however, notwithſtanding this paſſage, does paſs into the anterior ventricle; but all the blood which is received by the anterior ventricle is not ſent to the lungs, which before birth are too much condenſed to tranſmit ſo large a quantity; part of it is turned aſide by a veſſel called the ductus arterioſus, which paſſes from the pulmonary artery to the aorta. Thus, beſides the blood which eſcapes paſſing through the lungs by means of the paſſage from the anterior to the poſterior auricle, a ſecond portion eſcapes by the veſſel which leads from the pulmonary artery to the aorta, ſo that perhaps not more than a ſixth part of the blood which paſſes through the reſt of the body paſſes through the lungs before birth, whereas, after theſe paſſages are cloſed, every drop which is circulated in the body muſt neceſſarily circulate alſo through the lungs. Theſe paſſages, which are peculiar to the fœtus, from cauſes not aſcertained cloſe up very quickly after birth. The blood is returned from the fœtus by the arteriæ umbilicales which are the internal iliac arteries of the adult, but which in the fœtus paſs out at the navel, and are continued to the placenta.

The fœtus, which in the early periods of geſtation was almoſt all head, is ſtill at the time of birth of very different proportions from thoſe of the adult body; the head is remarkably large, and the lower extremities remarkably ſmall. The growth of the fœtus in the uterus is by no means uniform. The weight of children, when born at the full time, varies

from

from ſomething more than four pounds to a little more than eleven. By far the greater number weigh from five to eight pounds, avoirdupois. At the end of the third month, the bulk of the fœtus, with the membranes and placenta, is very inconſiderable, as is ſeen in abortions, which are moſt frequent at this period of geſtation. During the courſe of the fourth month the uterus becomes too large to remain within the pelvis, and riſing into the abdomen, gives ſome ſlight degree of protuberance. The fœtus now increaſes much faſter than before; but the principal part of its growth is performed during the three laſt months of geſtation, when the uterus at length riſes as high as the ſtomach, preſſing the inteſtines towards the backbone. The diſtended uterus is now ſtimulated to contraction, and the pains of child-birth are ſucceeded by the effuſions of maternal fondneſs.

It appears from a very accurate regiſter, kept by Dr. Clark, phyſician to the Lying-inn Hoſpital at Dublin, that the proportion of children is about *nine* males to *eight* females;—children dying under *ſixteen* days old, as *one* to about *ſix and an half*;—children ſtill-born, as *one* to *twenty*;—women having twins, as *one* to *ſixty*;—women dying in child-bed, as *one* to about *eighty-ſeven.*

There is, however, a greater mortality of male children, owing, as Dr. Clark ſuppoſes, to their greater ſize, and particularly to the ſize of the head, which becomes injured in parturition, and conſequently affects the health; and the proportion is reduced to quite equal before the age of puberty.

If every mother in a great city was obliged to ſuckle her own child, the proportion would be *one* good nurſe in *five*; and in the country, not *one* bad nurſe in *ten* *.

* Clark's Obſervations, Phil. Tr. 76.

CHAP. XLIII.

THE GROWTH AND DECLINE OF THE BODY.

Increaſe of the Body before and after Birth.—Diſproportion of the Parts decreaſes with Growth.—What Parts firſt ceaſe to increaſe in Size.—Youth.—Manhood.—Firſt Symptoms of Decline.—At what Period old Age generally commences.—Symptoms of Age.—Cauſes why the Human Frame cannot be of long Duration.

FROM the time of conception till birth, the growth of the body proceeds in an accelerated or increaſing proportion, that is, the growth in the ſixth month, for inſtance, is greater in proportion than in the fifth; from birth till manhood it is gradually leſs and leſs, in other words, the growth of the ſecond year is leſs in proportion than that of the preceding, and ſo of all the ſucceeding years.

The reaſon commonly aſſigned for the latter of theſe facts is, that the fibre becoming leſs diſtenſible from an increaſe of ſolidity as we advance in age, our growth is conſequently leſs rapid. But if the rapidity of growth was proportioned to the laxity of fibre, the fœtus ought to increaſe moſt rapidly immediately after conception, and more ſlowly as its texture becomes more firm. The contrary of this, however, is found to be the fact, ſince, in the early periods of geſtation the increaſe of the fœtus is very ſlow, and its growth is continually accelerated till the birth. From this ſtatement it muſt be concluded, that laxity of fibre is only one among other cauſes which favour the increaſe of the body. As the body advances in growth, its diſproportions are gradually loſt; the head increaſes

more ſlowly, and the lower extremities with more rapidity. The head indeed ceaſes to grow much ſooner than the other parts; for theſe, and particularly the thorax, ſeem to gain ſize and ſtrength for ſeveral years after the head has arrived at its utmoſt dimenſions.

At the age of fifteen or ſixteen years, ſooner in females than in males, and ſooner in warm countries than cold, the ſigns of puberty begin to manifeſt themſelves, and ſeveral changes now take place in the body, which it would be improper to ſtate.

When the body has attained its full growth and ſtrength, it does not immediately decline, but remains in a ſtate of nearly equal vigour till between forty and fifty years of age. At this time the body begins ſenſibly to loſe its agility, and the approaches towards old age, which had hitherto been inſenſibly going on, now begin to manifeſt themſelves.

But though the body has now loſt conſiderably of its agility, yet in perſons of good conſtitutions, and who have not been remarkably intemperate, its ſtrength remains pretty entire. After the age of fifty, however, the decline of body becomes much more apparent; there is no longer that ſpring and vigour of motion; and labour becomes more irkſome and painful. From the age of ſixty to that of ſeventy the health is frequently pretty good, but the ſtrength fails conſiderably. Threeſcore and ten years is the age of man; and though there may be ſome remarkable inſtances to the contrary, yet, in general, exiſtence protracted beyond this period is ſorrow and miſery.

In the whole progreſs of life the body is continually becoming leſs vaſcular. The vivid bloom of youth, which is owing to the ramifications of minute arteries in the ſkin of the cheeks, ſubſides into the moderate

hue

hue of middle life, and this into the wrinkled and ſhrunk appearance of old age. Similar changes are taking place in other parts of the body, and the coats of the arteries gradually becoming thicker and ſtronger with reſpect to thoſe of the veins; theſe latter become more diſtended, and the livid hue of venous plethora ſucceeds to the vivid tint of the arterious. A diſpoſition to ſolidity invades the body in the progreſs of life, and that which in the child was pliant cartilage, becomes in the old man brittle bone.

The quantity of earth in the compoſition of the different parts of the body is continually increaſing; the muſcles become inſenſible to the uſual ſtimuli; the vigour of the circulation is diminiſhed; and in the few, the very few, who eſcape the numerous pitfalls of diſeaſe and accident, this rigidity and inſenſibility increaſing, neceſſarily puts an end to exiſtence.

That modern diſcoveries, or the improvement of the medical art, ſhould be able to protract for any conſiderable period our mortal exiſtence, is a notion that will only be entertained by thoſe who are ignorant of the phyſiology of the animal frame, and indeed of every other branch of ſcience. It is the natural conſequence of extenſive knowledge to abate our confidence; while impudence, dogmatiſm, and vain and viſionary ſpeculation, are the genuine offspring of ignorance. Medical ſkill may indeed be ſucceſsfully applied in occaſionally arreſting the progreſs of thoſe diſeaſes, which might otherwiſe prematurely interrupt our mortal career; yet even in theſe inſtances, thoſe who have ſtudied moſt, and practiſed moſt, will be the moſt ſenſible of the impotence of human knowledge in this important art; but he who is at all acquainted with the delicate and fragile texture of the human frame

muſt be abundantly ſenſible, that it is a fabric which was not meant to endure for ever.

In the gradual decline of life, to which all muſt ſubmit, let us earneſtly embrace that conſolation which religion affords us. That which ſweetened the cup of death to Socrates is through life the cordial of the chriſtian; it is a conſideration that will moderate proſperity, and will deprive adverſity of its moſt poignant ſorrows; it will cheer us in life, and at the hour of death it is the only circumſtance that can impart a ray of comfort to the human ſoul.

Book X.

OF THE HUMAN MIND.

Chap. I.

OF THE STUDY OF THE HUMAN MIND.

Our Knowledge of Mind limited.—Confused by Metaphysics.—Plan of this Inquiry.—The First Part respects the Instruments and Modes of Action of the Human Mind.—The Second, the Springs or active Powers.—The Third, the most important Questions in Morals, &c.

"KNOW thyself," is a saying of great antiquity; and an author, whose sentiments are deservedly converted into maxims, has asserted, that "the proper "study of mankind is man." It is, however, a circumstance sufficient to mortify the pride of reason, that even on the subject most interesting to us, we must be content with a limited portion of knowledge; we must not extend our expectations too far. Even with respect to our own minds, there are some points which appear to be removed beyond the reach of our researches, while others are, perhaps unnecessarily, involved in doubt and disputation. It is unfortunate, indeed, that in no branch of science whatever the imagination has more wantonly sported than in this; in no science have men appeared so desirous of deserting the only sure guide, experience; in no instance has it

been thought proper to resort so little to proof and observation, or to attribute so much to conjecture and theory.

Metaphysical subtleties, and hypotheses carried to a visionary extreme, have, therefore, greatly contributed to confuse this branch of knowledge; though when extricated from these, I apprehend full as much is known in this science as in any other, and perhaps more than in most. On this account I shall carefully avoid all those disputed points concerning identity and diversity, existence, infinity, &c. that have divided the learned from time to time. I consider them, in truth, as utterly foreign to my purpose, and as tending to establish no one useful principle. It will be unnecessary also to examine the origin of our ideas, or to enter into nice disquisitions concerning space, duration, &c. &c. as such inquiries are certainly more curious than useful. I shall further avoid all fanciful theories respecting the nature of our perceptions. Some of them, I confess, are plausible, but I rather chuse to lay the ground work of my reasoning on actual experience; let those who so incline, extend at their leisure their researches further.

That scheme, which reduces the moral powers of man to the fewest principles, if these can be demonstrated adequate to every effect, is most satisfactory to the rational inquirer. The more of nature we discover, the more simple she appears in her operations: it is unphilosophical unnecessarily to multiply causes. It is evident, for instance, that there exists in men a relish for beauty, as well as for moral excellence, and an antipathy to vice and deformity. But how are these affections generated? It is an indolent method of philosophizing to stop at whatever is not easily understood. Final causes

and inherent inſtinct have ſaved the labour of many a painful inveſtigation.

With reſpect to the actual exiſtence of innate ideas or principles, the reader will perceive that I am not anxious to renew the controverſy. Innate ideas, I believe, have been in general given up by philoſophers ſince the time of Mr. Locke. A moral principle has, indeed, been contended for by ſome writers of the higheſt reputation, as being innate in man. It may be conſidered either as a ſixth ſenſe, as ſomething inſeparable from the ſoul or mind of man, or as a general inſtinctive reſult of his mental organization. I muſt obſerve, however, that the exiſtence of ſuch a principle has never yet been ſatisfactorily proved, though on the contrary it is not eaſy to diſprove it; I ſhall, therefore, as much as poſſible, avoid the controverſy, and endeavour, as far as obſervation enables us, to account for the operations of our minds in the ſimpleſt and eaſieſt manner, and to have as little recourſe as poſſible to principles which are involved in doubt or obſcurity.

The elementary part of this book will naturally divide into two branches. The firſt part will extend to the end of the eighth chapter, in which I ſhall endeavour to explain the inſtruments and the modes of action of the human mind. The ſecond will extend from the ninth chapter to the thirteenth, in which the ſprings or incentives that produce action in the mind, and influence its movements, will be examined.

The materials, upon which the human mind is principally to act, are the traces or veſtiges left by external impreſſions on the five ſenſes. Of theſe a ſimple effect on any one ſenſe produces what is called a *ſimple idea*, the word idea ſignifying an image or repreſentation in the mind of an action, quality, or ſenſation; thus *white* and *ſweet* are ſimple ideas.

An idea, compounded of ſeveral ſimple ideas, is called a complex idea, as man, horſe, tree, &c. which are evidently compounds of a number of ſimple ideas of figure, colour, ſolidity, &c. and ſometimes for diſtinction's ſake, when many *complex ideas* are compounded in one, the diſciples of Mr. Locke call it a *decomplex idea*, as *homicide*.

Impreſſions on the ſenſes are often ſo entwined or aſſociated together, that the idea of the one ſhall not be recollected without that of the other. This junction happens when two impreſſions are made on the ſenſes at the ſame time: thus the *whiteneſs* and *roundneſs* of a globe may be aſſociated; the form and the ſound of a muſical inſtrument; the name with the thing, ſo that on the ſight of the thing or object we immediately recollect the name. Ideas may aſſociate with impreſſions, if an impreſſion is made on any of the ſenſes, while an idea is predominant in the mind. Thus the ſight of a particular place will often recal ſome intereſting train of thought, that may have been entertained there. When I ſpeak of ideas being aſſociated, connected, combined, &c. I would be underſtood of the ſame thing, viz. the implexion or junction of ideas thus explained.

The retention of ideas in the mind is called *memory*. The act of combining old ideas into new ones, *invention*, and frequently imagination or fancy. The act of examining and comparing them *judgment*. Under theſe heads I propoſe explaining the primary operations of the mind, and theſe will conſtitute the firſt part of the preſent inquiry.

The ſecond part of this book will conſiſt of an inquiry into the common ſprings of action in the mind. Theſe I ſhall endeavour to prove to be ultimately the ſenſes of *pleaſure* and *pain*. *Love* is the idea of pleaſure,

combined with ſome other idea; *hatred* the idea of pain, combined in the ſame manner. *Deſire* and *averſion* are active love and hatred *.

The third part, which extends from the thirteenth chapter to the concluſion of the work, will conſiſt of the application of theſe principles to the inveſtigation of ſome curious ſubjects, and to the theory of morals. This, as it is the moſt extenſive part of the ſubject, is neceſſarily the moſt imperfect, and the chapters that conſtitute this part, are rather exhibited as confirmations of the preceding principles, than as a complete ſyſtem.

* The *natural appetites* of man are,

1. The common call of *nouriſhment* for the body. 2d. The deſire of propagating the ſpecies.

The natural pleaſures of man are,

1ſt. The ſatisfying of theſe appetites. 2d. The general pleaſure reſulting from the moderate and proper exerciſe of the organs or faculties.

CHAP. II.

OF PERCEPTION.

The Senſes the great Source of Information.—Diſtinction between Senſation and Perception.—Senſes correct each other.—Whether the ſame Objects produce ſimilar Perceptions in different Men.—Ideas.

THAT the mind is obliged to the ſenſes for the great maſs of its information, is now an eſtabliſhed principle. The proofs of this doctrine I ſhall decline entering upon for reaſons already aſſigned. I would only obſerve, Firſt, That I do not ſee why we are furniſhed with ſenſes by the author of nature, if not for this purpoſe. Secondly, The ſenſes ſeem entirely adequate to all the information we are poſſeſſed of. Thirdly, Perſons wanting any of the ſenſes appear entirely deſtitute of the ideas of that ſenſe. A gentleman, blind from infancy, aſſured me, he never remembered to have experienced in a dream any thing like what the ſenſe of ſeeing is deſcribed to be. Nay, thoſe who have all the ſenſes complete, derive plainly their knowledge from the exerciſe of them. A child does not ſhrink from a candle till it has felt the painful ſenſation of burning, or is warned againſt it in terms expreſſing pain, of which it forms a judgment from pain already experienced.

A very proper diſtinction is made by Dr. Stuart, between ſenſation and perception. Senſation implies " that change in the ſtate of the mind which is produced by an impreſſion upon the organ of ſenſe; of which change we can ſuppoſe the mind to be conſcious without any knowledge of external objects. Percep-

tion expresses that knowledge we obtain, by means of our sensations of the qualities of matter *.

† Sensations may be communicated from without; 1st. by actual contact with the object itself; 2dly. by the intervention of some medium; and it amounts to the same, whether we perceive the qualities of bodies by a communication with the bodies themselves, or by the effects which they uniformly produce on some medium which communicates with our senses. Thus, when we see a body *white*, we do not say that the light is perceived by our senses, but the whiteness of the body, or that property in the body which so disposes the rays of light as to afford us the perception or idea of *white* ‡. When, therefore, we speak of smells, tastes, colours, sounds, we mean that certain effects are uniformly wrought upon our senses in certain

* Outlines of Mor. Phil. p. 21, 22.

† The different senses by whose operation we discern the qualities of external objects, have been already stated to be five in number. Touching, tasting, smelling, hearing, and sight. They may perhaps all be resolved into that of feeling; yet the distinction is correct, as they are certainly different instruments of feeling or perception. In those of touching and taste an actual contact with the body, which is the object of the sense, is requisite. In the others the sensation is effected through the operation of some medium. Thus sight is in reality the effect of the rays of light upon our optic nerve; sound is a vibration of the air, which affects the organs of hearing; and smell depends upon the emanation of certain particles from a body, which act upon the organ of scent.

That some senses are more acute in certain animals than in others, is an obvious fact. The power of smelling in some of the canine species is beyond any thing that we are able to conceive. Cats and owls have undoubtedly a power of seeing with a much smaller portion of light than any human being. It is probable that in different men some senses may be more acute than others.

‡ There is undoubtedly something in objects which excites sensations, but the sensations themselves cannot exist without a subject

tain circumſtances, and to the unknown cauſes we aſſign theſe names.

The information of the ſenſes is the laſt reſort of human reaſon; I mean their joint information, for it appears they correct each other. It has been already ſtated, that the judgments we form of material things are not ſo much the effect of an impreſſion on any one ſenſe as of thoſe of ſeeing and feeling combined*. Simple impreſſions or perceptions are not to be defined, nor do they, from that agreement and analogy which exiſts between the ſenſes of all mankind, require definition.

It is of no conſequence whether the ſenſes of different men perceive exactly alike, though it is probable there is not much difference in this reſpect. It is of no conſequence, whether one man ſees objects larger than another, or whether the ſame compoſition affords to each preciſely the ſame taſte or ſmell. We communicate our ideas of ſenſations by the help of relation; we call a thing ſmall when compared with another; we call the taſte of a certain viand ſweet, or a ſound grave or deep, and we have nothing further to do to be clearly underſtood, than to mark the proportionate differences and relations.

It is to be remarked, that all objects that preſent themſelves to our ſenſes do not make ſuch impreſſions as to leave ideas behind them. Many times the mind is too much engaged with one train of thoughts to admit another. An impreſſion or ſenſation being

on which to act. The diſputes therefore of philoſophers, whether ſmells are in the noſe or in the perſon who ſmells them, &c. &c. are merely *de lana caprina*; and there muſt be a union of cauſes to produce ſuch effect. Such diſputes may ſerve to exerciſe the human faculties, but they undoubtedly make no addition to our ſtock of real knowledge.

* See Book 9. c. 37.

perceived by the mind, the trace or veſtige it leaves behind is called an *idea.*

Whether the mode of conveying perceptions from the ſenſes to the underſtanding, is by a vibratory motion of the nerves * or by any other means, is of no conſequence to the preſent inquiry. It is ſufficient to ſay, that the ſenſes are firſt affected by external objects, that theſe impreſſions leave behind them veſtiges which are called ideas, and from the natural or voluntary combination of two or more of theſe, a new idea may be formed.

* Such is the theory of the ingenious, but viſionary Hartley.

CHAP. III.

OF IDEAS.

Ideas of Senſation and Reflexion.—Simple and complex.—Modes and Subſtances.

IDEAS being the images of impreſſions, want their force and vivacity. 1ſt, Ideas of ſenſation are the mere repreſentations of effects wrought on the ſenſes. 2dly, We give names to the particular actions of our own minds, as perception, thinking, doubting, reaſoning, and theſe Mr. Locke calls ideas of reflection *.

It is probable many of our firſt ideas are complex, that is, the reſult of ſeveral ſenſations combined or united together. A child will hardly diſtinguiſh between the figure and colour; as in a glaſs globe, it will have the idea of the globe itſelf, before it will diſtinguiſh between the roundneſs and the brightneſs of which it is compounded; they are nevertheleſs as diſtinct ideas as ſweetneſs and hardneſs, which may exiſt in the ſame ſubſtance, and one of them not be perceived as united with the other. "Though the hand feels ſoftneſs and warmth in the ſame piece of wax, yet the ſimple ideas in the ſame ſubject are as perfectly diſtinct as thoſe that come in by diſtinct ſenſes." Simple ideas will be recollected in objects differing in every reſpect but that one, from thoſe by which we originally received them. Though a horſe, for inſtance, may poſſeſs no obvious quality

* Locke, B. 2. c. 2.

in common with a book, but that of external colour, as blackneſs, yet that quality will be recollected to be the ſame in both; and thus we learn that colour is not the neceſſary concomitant of figure, by finding the ſame colour united with different figures; and in the ſame manner, probably, we learn to disjoin all thoſe ſimple ideas that enter by the ſame ſenſe, as ſolidity and warmth, &c. &c *.

All our ideas of ſubſtances are complex, and are compounded of the various ſimple ideas jointly impreſſed, when they preſented themſelves to our ſenſes. We define ſubſtances only by enumerating thoſe ſimple ideas; and ſuch definitions may ſometimes produce an idea tolerably clear of the ſubſtance, in the mind of one who never immediately perceived the ſubſtance itſelf; provided he has ſeparately received by his ſenſes all the *ſimple ideas*, which are in the compoſition of the complex one of the ſubſtance defined †.

Words repreſenting complex ideas do not always preciſely excite the ſame idea in different perſons. Some of the ſimple ideas may have made a ſtronger impreſſion on one man than another, and ſome may have totally eſcaped him. The word *man* will, with a painter, call to mind ſeveral minute circumſtances in the external appearance; with an anatomiſt the ſkeleton, nerves, &c. will hardly eſcape animadverſion;

* "The moſt enlarged underſtanding cannot frame one new ſimple idea; nor by any force deſtroy thoſe that are there."

Locke.

† The word ſubſtance generally applied, means no more than the ſuppoſed, but unknown ſupport of thoſe qualities, which are capable of producing ſimple ideas in us. The ideas of particular ſubſtances, are compoſed from ſuch combinations of ſimple ideas as are obſerved to exiſt together, and ſuppoſed to flow from its particular internal conſtitution. Locke, B. 2. c. 28.

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with a metaphyſician, the mind, or more properly the modes of acting, the powers and faculties will be recollected. In all complex ideas, however, which are the immediate objects of ſenſe, and which are not decomplex, or compoſed of ſucceſſive impreſſions, the more obvious qualities will ſerve to mark the idea, and identify it to every man; as the idea, *horſe*, *tree*, &c. can never be differently apprehended. It is otherwiſe with more abſtract and remote terms; the word *virtue* may be very widely conceived of by different perſons, as the cuſtoms of their countries, the courſe of their ſtudies, or their turn of thinking, may determine; hence in all arguments, terms ſhould be minutely defined.

All complex ideas are combinations of ſimple ideas aſſociated together, as will be explained in the chapter of aſſociation.

Beſides this diviſion of ideas into ſimple and complex, logicians have adopted others, which it may be of ſome uſe briefly to explain *. A principal diviſion is into ſuſtances and modes, that is, modifications of matter or forms of exiſtence.

Hence follows a diviſion of modes into *ſimple* and *mixed modes*. Simple modes of *duration*, are whatever diſtinct ideas we have of any parts of it, as hours, days, &c. &c. Simple modes of *colour*, are white, blue, &c. &c. Simple modes of *ſpace* are any particular lengths of it, as an inch, a foot, &c. Simple modes of *motion*, are ſliding, walking, &c. It would be uſeleſs to enter into any more particulars of this kind, as theſe diſtinctions are pointed out rather with a view to the works of others than to the preſent treatiſe. I would wiſh to obſerve, that the general terms *colour*, *ſpace*,

* See Locke, B. 2.

&c.

&c. do not furniſh any *diſtinct* idea; we can have no clear idea, but of a particular colour, &c. as will be explained when I come to ſpeak of words.

Mixed modes are defined by Mr. Locke to be "ſuch combinations of ſimple ideas, as are not looked upon to be the characteriſtical marks of any real beings that have a ſteady exiſtence; but ſcattered and independent ideas, put together by the mind, are thereby diſtinguiſhed from the complex ideas of ſubſtances *," ſuch are *hypocriſy*, *drunkenneſs*, &c. The ideas of mixed modes are acquired firſt from experience; as by ſeeing two men wreſtle, we acquire the idea of *wreſtling.* 2d, By putting together in the mind ſeveral ſucceſſive actions, as a *lie.*

* Locke, B. 2, c. 22.

CHAP. IV.

OF ASSOCIATION.

Synchronous Associations.—Successive Associations.—A great Part of our Knowledge dependant on the latter.—Common Sense.—Train of Ideas.—In what Manner the Train of Ideas is carried on.—Relations of Contiguity, &c.—How these are formed in the Mind.—How the Train of Ideas is regulated.—Influence of the Will.

THE word association was, I believe, first used in this sense by Mr. Locke; the doctrine is notwithstanding very ancient. Plato and Aristotle in many of their writings, evidently allude to this connexion of ideas. Some of the Stoics remark its effects in speaking of custom, opinion, &c. and Antoninus is very clear upon the topic *. Hobbes has a whole chapter upon the train of ideas †, and makes considerable use of the doctrine through the whole of his work.

* Οια αν πολλακις φανταϑης; Τοιαυτη σοι εςαι η διανοια. Βαπτεται γαρ υπο των φαντασιων η ψυχη.—Anton. l. 5. c. 16.

† " In a discourse on our present civil war (says he) what could seem more impertinent than to ask, as one did, what was the value of a Roman penny? Yet to me the coherence was manifest enough. For the thought of the war introduced the thought of the delivering up the King to his enemies; the thought of that, brought the thought of the delivering up of Christ; and that again the thought of the thirty pence, which was the price of that treason: and thence easily followed that malicious question; and all this in a moment of time; for thought is quick."—Leviathan, pt. 1. c. 3.

I do not in fact find that any one discovery has been made in the science of mind since the time of Hobbes.

Two sensations happening at the same time will become united, and the ideas will be united of course; thus the ideas of the figure and colour of bodies, admitted by the eye, are united, and these may be united with another idea admitted by the touch. As the ideas of roundness and whiteness by the former, and solidity by the latter, are associated together in the complex idea of a stone. If music is heard, while we behold the instrument, the sound will be associated with the visible appearance, and the former will at any time recal the idea of the latter, when we do not see the instrument *. Names become associated with things, and things with actions †. Associations formed from impressions made at the same time, are called synchro-

* "The names, smells, tastes, and tangible qualities of natural bodies, suggest their visible appearances to the *fancy*, and vice versa."—Hartley on Man, c. 1. s. 1. prop. 5.

† "It is remarkable, however, as being agreeable to the superior vividness of visible and audible ideas, that the suggestion of the visible appearance from the name, is the most ready of any."—Ibid.

'The transition from the words to the ideas, is generally much easier than from the ideas to the words. A person who is learning a strange language, will be able to understand a book in that language long before he can write or speak it. Even in one's native tongue, one can readily understand what is written or spoken in the best and properest terms, though he could not have used these terms for expressing the same ideas. This proceeds from the influence of custom, &c. The ideas are more *familiar* to us than the words: they are often raised by their proper objects, or suggested by other words: and their *familiarity* makes them be suggested readily. That this is the true cause, is confirmed by observing that where it does not take place, ideas are not suggested more readily than words are in ordinary cases. When the ideas expressed are such as we have been little accustomed to attend to, a discourse or composition is understood by us with difficulty, as well as when ideas are expressed by unusual words.'—Gerard on Gen. pt. 2. s. 2. note.

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nous. But it is evident that impressions remain some moments on our senses, and die gradually away *; if another impression therefore is made while the former remains, they will be associated, and the one shall recal the other to remembrance; the association being weaker or stronger in proportion to the state of the idea or impression with respect to its vividness. An idea may in the same manner be associated with an impression or sensation, or two ideas may be associated together, and this kind of association from contiguity of time may be termed successive. Those complex ideas which are formed from synchronous impressions, are more vivid and distinct than those formed from successive ones.

Propositions founded upon synchronous impressions, are little else than complex ideas of sensation; as in the proposition "the dog barks," the idea of the thing is as much associated with the action as with any of its qualities: and here is no room for dissent, unless we could find that our senses had deceived us.

Propositions founded on successive impressions, are much more liable to error; yet of these consistsby far the more valuable portion of our knowledge. It is remarkable, how in forming these propositions, frequent experience leads us to drop the intermediate ideas, and connect the two extremes of the proposition, calling it self-evident, as if it was really the effect of synchronous impressions. "We may observe (says Mr. Locke †.) that the ideas we receive from sensation, areoften in grown people altered by the judgment without our taking notice of it. Thus a globe of any uniform colour, as of gold or jet, being set before our eyes, the idea thereby imprinted, is of a flat circle va-

* See Sir Isaac Newton's Optics, and b. ix. c. 41.

† B. 2. c. 9.

riously shadowed. But being accustomed to perceive what kind of appearances convex bodies are wont to make in us; the judgment alters the appearances into their causes; and from that variety of shadow or colour, frames to itself the perception of a convex figure of one uniform colour." A man who reads or hears with attention, takes little notice of the characters or sounds, but of the ideas that are excited in him by them. Thus we find the intermediate, associating ideas are dropped, and the more remote causes immediately connected with the effects. In the instance of the globe, the first complex idea presented, is that of a circle associated with certain shades of colour; on approaching and examining it by the touch, we find that this is really a convex figure and of a self-colour, we therefore associate the ideas of the convexity and colour with the former idea of the circle so shadowed, and the one occurs not alone, but always accompanied with the other, and so immediately, that we feel it as if it had been from synchronous impressions. The association soon becomes so strong that we are liable to be deceived by it, for when we see objects well painted on canvas we can scarcely conceive that they are represented by different shades on a flat surface, and a child very naturally employs his feeling in order to satisfy himself. It is unnecessary to multiply instances; it is obvious that the sight of blood never fails to alarm the mind instantaneously, though no more productive of fear or horror from its natural properties than any other fluid. "Painters, statuaries, anatomists, architects, see at once what is intended by a draught, picture, &c *." Something like this occurs in moral propositions, as, "intemperance is productive of ill

* Hartley on Man, prop. 23.

health."

health." Here it is plain that common experience ſo frequently unites the conſequence to the cauſe, that omitting all the intermediate ſteps neceſſary to form the concluſion, the mind is ſatisfied with the aſſertion, and calls it ſelf-evident. This is what ſome authors (if I am not miſtaken) mean by *common ſenſe*; and indeed theſe concluſions are ſo generally right, that although it may be for the intereſts of virtue, occaſionally to examine them by the principles of reaſoning, men in moſt caſes have very little occaſion for any other appeal than to their common feelings, to determine on the juſtice or injuſtice of particular actions; ideas of juſtice being founded in the truth of things, and ſo confirmed by experience, that the concluſions are as ready at hand, and almoſt as clear as that "the ſun ſhines;" "what is, is;" or any other of thoſe maxims that are really ſelf-evident.

On this principle of aſſociation depends the neceſſary ſucceſſion of ideas in a train, of which any one may ſatisfy himſelf by attending to the operations of his own mind. Ideas are introduced by an agreement in ſome of the parts of which complex ideas are compoſed. Shakeſpear, deſcribing a merchant's fears, ſays,

> "My wind, cooling my broth,
> "Would blow me to an ague, when I thought
> "What harm a wind too great might do at ſea.
> "I ſhould not ſee the ſandy hour-glaſs run,
> "But I ſhould think of ſhallows and of flats;
> "And ſee my wealthy Arg'ſie dock'd in ſand.
> "Should I go to church,
> "And ſee the holy edifice of ſtone,
> "And not bethink me ſtrait of dangerous rocks*?"

It is remarked, that the train of ideas almoſt always depends upon the relations of contiguity in time or

* Merchant of Venice, ſc. 1.

place, cauſe and effect, reſemblance or contrariety; all of which it is obvious, depend on the principles of aſſociation already explained. It has been fully proved, that ideas are aſſociated by contiguity of time; the former impreſſion remaining vivid ſome moments after it was firſt made, and the other during that time occurring, they become united. That aſſociation which ariſes from unity of place is no other than recollection, the place making a part of the complex idea of any action. Cauſe and effect are aſſociated by contiguity of time; for, as Mr. Locke obſerves, "we get theſe ideas from our obſervation of the viciſſitude of things, while we perceive ſome qualities or ſubſtances begin to exiſt, and that they receive their exiſtence from the due application and operation of other beings *." The relation of reſemblance is no other than recollection of that particular idea, in which the object preſent, and the object remembered, agree. When two ideas are formed, agreeing in any quality or qualities, they are ſaid to be related; and the degrees of relation are as they agree in fewer or more qualities. Reſemblance in one ſimple and very common quality, as black, round, &c. will ſeldom recal an idea, unleſs very recently or very ſtrongly imprinted, the mind being confuſed with the multitude of objects poſſeſſing that quality.

The aſſociation of ideas with their contraries ſeems to ariſe, 1ſt, When the idea ſo remembered is only a negative idea, and derives its exiſtence from its poſitive; thus cold is the want or decreaſe of heat; ſickneſs is the want of health; poverty of riches; &c. 2d, When the ideas are connected in point of time †,

* Locke, B. ii. c. 26.

† "Eye-witneſſes generally relate in the order of time, without any expreſs deſign of doing ſo."—Hartley on Man.

as muſt be the caſe in a change from one ſtate to another, ſuch are the ideas *danger* and *ſafety*. 3d, Perhaps two things, which are oppoſite, being perceived at once, the mind is more forcibly ſtruck by each of them, the ideas are conſequently more vivid, and more liable to be recollected.

The train of ideas is often regulated by ſome *end* propoſed to ourſelves; for where we have an object in view, ſuch ideas as are connected with it will of courſe be ſuggeſted. By theſe means we are frequently impoſed on; a paſſion or an intereſt will lead on a train of arguments favourable to them, while we imagine we are acting with the utmoſt impartiality *.

'The indirect influence of the will,' ſays Dr. Stuart, 'over the train of our thoughts, is very extenſive. It is exerted chiefly in two ways:—1ſt, By an effort of attention we can check the ſpontaneous courſe of our ideas, and give efficacy to thoſe aſſociating principles which prevail in a ſtudious and collected mind; 2d, By practice we can ſtrengthen a particular aſſociating principle to ſo great a degree, as to acquire a command over a particular claſs of our ideas.'

* 'Should any one be ſurpriſed at this diſpoſition in our nature to aſſociate any ideas together for the future, which once preſented themſelves jointly, conſidering what great evils, and how much corruption of affections is owing to it, it may help to account for this part of our conſtitution, to conſider, "that all our language, and much of our memory, depends upon it;" ſo that, were there no ſuch aſſociations made, we muſt loſe the uſe of words, and a great part of our power of recalling paſt events, beſide many other valuable powers and arts which depend upon them."

Hutchinſon on the Paſſions, ſ. i. p. 11.

Chap. V.

MEMORY*.

Ideas of Memory.—Distinguished from Ideas of Imagination.—Judgment concerning Distance of Facts.—Memory in young and old Persons.—Recollection.—Certainty.

IT appears, that ideas of memory are distinguished from ideas of imagination; 1st, By being more vivid; 2dly, By the associated ideas of time, place, and other circumstances that accompany them.

As ideas, by being often repeated, become more vivid, it is a common remark, that persons inclined to habits of falshood, by often repeating the same story, are themselves at last imposed on by the vivacity of the idea, so as to mistake it for an idea of memory. Madmen are almost always deceived in this way. In dreams, the vividness of the new scene, and no associated ideas appearing by which to mark those ideas derived from memory, cause us to mistake them for a series of real impressions.

It seems probable, that we judge of the distance of facts recorded by the memory, 1st, From the idea growing fainter, yet retaining the principal associated circumstances; 2dly, From enumerating ideas of facts, which we know, by the order of ideas, to have successively happened since that point of time in which the idea first occurred. 'The death of a friend, or any interesting event, often related, appears to have hap-

* 'Memory is that faculty by which traces of sensations and ideas recur, or are recalled, in the same order and proportion, accurately or nearly, as they were once actually presented.'—*Hartley on Man, Introduc.*

pened

pened but yeſterday, as we term it, on account of the vividneſs of the idea correſponding to the nature of a recent event *. Miſtakes are here prevented in perſons, who retain their ſenſes, by the ſecond means of judging, viz. by enumerating facts that have ſince occurred, &c.

Memory is weak in children; 1ſt, Probably, becauſe the organs are flaccid and weak; 2dly, For want of a number of ideas, which experience furniſhes, and which afterwards ſtrengthen the powers of aſſociation. Memory is ſlow and defective in old perſons; 1ſt, Becauſe, probably, a rigidity of fibre may render the organs of thought leſs active; 2dly, Becauſe the paſſions are weaker, there is in reality leſs life, of courſe a ſluggiſhneſs of mind will generally accompany that ſtate. Impreſſions are eaſily made on the ſenſes of children, but do not remain. On the contrary, it is difficult to make ſuch impreſſions on older perſons as to produce ideas, but when made they are laſting. Hence the neceſſity of inuring the mind to action and ſtudy through every ſtage of life, ſuch perſons frequently retaining their mental agility and powers longer than others.

Ideas are more eaſily recollected, 1ſt, By being vividly and diſtinctly impreſſed; 2dly, By being ſtrongly aſſociated. Theſe two cauſes will generally concur, for the more vivid an impreſſion is, the longer it remains on the ſenſe, and of courſe the more ideas it will be aſſociated with. A ſentiment when quoted from a book or a poem by another author, as appoſite to his ſubject, often makes a more diſtinct and vivid impreſſion than in the original writer. The impreſſion is more vivid, becauſe we are apt to fancy that ſome peculiar excellence induced another author to quote it; it is more vivid too, becauſe it is more diſtinct; it is

* Hartley on Man, prop. 42.

better remembered, both for this reaſon, and becauſe (like all diſtinct ideas) it becomes aſſociated with time, place, and other circumſtances, as well as with the ideas of him who quotes it *.

The following are the modes of memory pointed out by Mr. Locke, which may be of ſome uſe as definitions. ' When an idea recurs without the preſence of the object, it is called *remembrance*; when ſought after by the mind, and brought again in view, it is *recollection*; when held there long under attentive conſideration, it is *contemplation*; when ideas float in the mind, without regard or reflexion, it is called *reverie*; when the ideas are taken notice of, and, as it were, regiſtered in the memory, it is *attention*; when the mind fixes its view on any one idea, and conſiders it on all ſides, *ſtudy* †.'

That ideas are commonly recollected in a train has been already noticed. It has, indeed, been diſputed, whether we have any further power in recollection, than, 1ſt, Exciting a certain degree of activity in the mind, and awakening it to the different aſſociations ‡;

* ' We remember that beſt, which we underſtand moſt perfectly. What we underſtand, ſtrikes us with its whole force: of what we underſtand imperfectly, it is only the part underſtood that makes any impreſſion on us; of the reſt we have no perception; even that part makes but a faint impreſſion. It would acquire additional force from its connexion with the other parts, if the whole were underſtood.' —*Ger. on Gen.* part ii. ſ. 9.

† Locke, B. ii. c. 19.

‡ ' The mention of a perſon often makes us recollect, that there is ſome purpoſe for which we want to ſee him; but ſometimes, when we cannot call to mind what it particularly is, the ſight of that perſon brings it quickly into our thoughts. In conſequence of the ſuperior force of ſenſations, which enables them to ſuggeſt conceptions by means of much weaker relations than ideas can, it often happens, that an object occurring to the ſenſes gives a very quick and ſeemingly unaccountable turn to the courſe of the thoughts.'—*Gerrard on Gen.* part ii. ſ. 3.

and,

and, 2dly, When two trains of ideas occur, directing the attention to one in preference to the other. The order of time, place, &c. have great influence in recollection.

In recollecting a company, we are obliged to have respect to the order of place, to the course of conversation, or some other of the common relations. Recollection in order of time happens from some part of two ideas becoming entangled with each other, as the mind, when waking, is seldom without some idea, so no one is perfectly gone before the introduction of another. Recollection from place happens by the transition which the mind makes from the first idea to the place, and from the place to the second idea; it is the same in recollection from resemblance. Recollection from cause and effect is the same as recollection in order of time; only it is to be remarked, that we look upon every thing as being both a cause and effect of some other thing, though of what, or in what manner, we may be ignorant; and this is the result of experience.

An idea frequently recollected becomes associated with a number of other ideas in the different repetitions of it; it will therefore be more predominant, and more apt to be recalled on future occasions; and this constitutes the power of habit over our turn of thinking, which may be acquired from reading frequently the same book, or conversing much with the same person.

Distinct memory thus depending on association, the simple ideas are often found to remain, while the circumstances first connected with them are utterly lost. These the mind forming into new combinations, we call invention.

As memory is so much dependant on association, it is evident, that what influences the latter will have

much effect in determining the peculiar excellence of any man's memory. Some are found to have a memory adapted to the remembrance of historical facts, some to poetry, &c. Ideas formerly received are so many hooks (if I may be allowed the expression) that fasten on those ideas which assimilate with them.

The distinctness, liveliness, and connected circumstances of ideas, leave almost no room for mistakes in judgment, as far as depends on the memory. Ideas of memory, by frequent repetition, may be retained equally perfect and vivid as when first imprinted; it follows, therefore, that when, from the clearness and vividness of the ideas, we feel that they have remained unconfused in the mind, our reasoning, as far as respects them, will fall nothing short of absolute certainty.

How far the memory is dependant on the corporeal organs, has been often disputed. Some striking instances, to prove a very close dependance, have been furnished by different authors. An Italian poet is related to have fallen dangerously ill, and when he recovered, to have forgotten the very letters of the alphabet. Pliny speaks of a person, who, by a dangerous fall, forgot his mother and friends. Messala Corvinus, by a disease, forgot his own name. Valerius Maximus relates, that a citizen of Athens, by a blow of a stone on the head, forgot all he knew of polite literature, though in other respects he retained his memory *. In the Memoirs of the Royal Academy, 1711, there is an account of a young man, who, in a fever, forgot every thing he knew; but afterwards learned very quickly; so, retaining his faculties, he lost his former ideas †.

* Plin. Nat. Hist. l. vii. c. 24.

† See instances of extraordinary memory, Plin. Nat. Hist. l. vii. c. 24.

We

We muſt, however, be cautious of giving too implicit credit to theſe relations. Authors, as well as all other men, are too fond of the marvellous. It is certain, that the ſoul or mind of man cannot act, unleſs the inſtruments with which it is to act are in a proper ſtate. The mind is, therefore, affected by the infirmities of the bodily frame; yet, in lunacy, and other mental complaints, medicine is found to have but a feeble effect. That a perſon, from a mere corporeal injury, can have any *one* ſubject eradicated from his memory, while he retains others, is not to be believed.

Extraordinary and minute powers of memory are ſeldom conſiſtent with imagination. The mind, in that caſe, ſeems to be too much occupied with old ideas to be diſpoſed to form new ones. I have heard a gentleman, of a remarkably ſtrong memory, complain, that when he ſat down to compoſe, he experienced great difficulty, from being incumbered with the thoughts, ſentiments, and language of other authors.

CHAP. VI.

OF INVENTION.

Invention; what.—Ideas of Memory and Imagination.—Invention and Judgment.

THE mind may be equally employed in making true as falſe combinations of ideas; in forming a ſyſtem, and connecting ideas by their natural relations, as in depicting Centaurs, and making witty alluſions; in either of which caſes it is ſaid to *invent.* In the former there ſeems to be a greater mixture of judgment, and this kind of invention is ſubſervient to real ſcience. On the contrary, when the invention conſiſts in drawing ſtrong and lively pictures or repreſentations, either falſe in themſelves, or heightening by rhetoric real facts, it is called *imagination*; when it conſiſts in wild and unexpected combinations, it is called *fancy* *.

From the two laſt chapters it appears, that invention is altogether dependant on the principle of aſſociation. When a perſon is poſſeſſed of a mind ſufficiently active to be eaſily affected with the relations pointed out in the preceding chapters, we ſay of him, that he has an inventive genius: a quick diſcernment of thoſe relations between complex ideas, will lead him to combine them into new ones, or to new arrange the order of his thoughts, which will amount to nearly the ſame. In an active mind, the ideas will be more vivid, and ſuch a mind will take notice of many relations that would

* "When ideas, and trains of ideas, occur, or are called up in a vivid manner, and without regard to the order of former actual impreſſions and perceptions, this is ſaid to be done by the power of imagination or fancy."—*Hart. Introd.*

escape ordinary persons. When a mind is more conversant, and more affected with the relation of cause and effect, such will constitute a genius for the sciences. A genius for the arts is more forcibly struck with the relation of resemblance.

Hence, first, it follows, that the memory must be strong to supply a genius for either arts or sciences with materials for new improvements; and, 2dly, The mind must be active, and easily affected by the several relations.

The distinction between ideas of memory and ideas of imagination has been already mentioned. Ideas of memory must necessarily be more lively than ideas of imagination commonly are at first. Ideas of imagination are only formed from the ideas of memory, so that at most the figure is but at second-hand, and must also be less perfect than what nature has actually presented to our senses. Yet, if we remember what was said respecting the frequent repetition of an idea, it will be found, that ideas of imagination may, by this means, become fully as vivid as ideas of memory, which is the case with persons addicted to falshood, as has been already remarked. But I will even go beyond this, and assert, that a number of vivid ideas, being combined into one complex one, and each having its dependant train of ideas, the complex, or rather *decomplex* idea, by frequent repetition, will produce a stronger sensation than any one of its constituent parts. Hence it is a self-evident fact, that the intellectual pleasures and pains, though deducible from the sensible ones, are in reality stronger and more vivid, as any person may satisfy himself who considers a little the nature of *avarice*, *ambition*, or *love*.

It has been customary to establish a radical distinction between invention and judgment, as if they were

6 distinct

distinct powers of the mind, and not the same power differently employed; but the only two great distinctions that I perceive in the human mind are, memory and genius, which, it is certain, do not always meet in the same person. Perhaps the reason they are seldom found to exist together *, in any considerable extent, may be a certain inertness in minds of the former cast, which enables them to retain ideas in the gross, but which disables them from separating, analizing, or making new combinations. A very vivid mind is not only struck with an object as a whole, but every constituent part is observed, and makes, if I may so express it, a separate impression; these parts are, therefore, liable to become separately associated with parts of other complex images, and the same vividness and activity of mind will produce naturally these frequent associations.

* I would not be understood to represent memory, and even very strong powers of memory, as inconsistent with *genius*; on the contrary I am well assured, that a good memory is one of its essential constituents.—I would be understood to speak of those uncommon memories which retain not only the ideas, but the language of authors, and which will recollect with little trouble not only the substance, but the words of voluminous productions.

Chap. VII.

OF JUDGMENT.

Judgment; what.—Assent.—Probability.

WHEN the mind examines and compares objects or ideas, recalling in a series, and turning them over, so as to distinguish their natures, qualities, or relations, it is said to judge. To the act itself, or the power of performing it, we give the name judgment, and often the conclusion or inference is called a judgment.

Ideas are objects of the judgment; first, in distinguishing one idea from another: this act of the mind has given rise to the technical terms used by logicians, *identity* and *diversity*. Mr. Locke calls this the first act of the mind, which, he observes, "it does without any pains or deduction, by its natural power of perception and distinction." 2dly, Ideas are objects of the judgment, in perceiving the relation which one bears to another, or the particulars in which they agree one with another. Thus, by the first, we observe, that blue is not purple; and yet, by the second, we perceive, that purple approaches nearer the colour blue than yellow does. Or, to give a plainer instance—We perceive by the first act of judgment, that two is a different number from four; and, by the second, that they have this property in common, that they are both even numbers.

Mr. Locke observes, that truth and falsehood belong properly to propositions *. Truth is, first, a

* B. ii. c. 32.

conformity

conformity of the idea with the name; in other words, that in the minds of different persons the same name shall suggest the same idea. 2ndly, A conformity of the idea with some real existence. 3dly, A conformity of one idea with another.

The cause that a person affirms the truth of the proposition, twice two is four, is the entire coincidence of the visible and tangible idea of twice two with that of four, as impressed upon the mind by different objects. We see every where that *twice two* and *four* are only different names for the same impression. Where the numbers are so large, that we are not able to form any distinct visible ideas of them, as when we say, twelve times twelve is equal to one hundred and forty-four, a coincidence of the words arising from some method of reckoning, and resembling the coincidence of words, which attends the coincidence of ideas in the simpler numerical propositions, is the foundation of our rational assent; for we often do, and might always verify the simplest numerical propositions by reckoning up the numbers *.

Those judgments, which relate to determining the probability of future events, appear to be little more than accurately remembering, and selecting such principles as relate to the matter in contemplation. We can guess at the future only from the past. As when certain appearances happen, we remember, that the same apppearances were formerly attended with certain consequences; the whole event is therefore presented to our minds, though not yet completed. The great difficulty is, to recollect accurately in what particular circumstances the present matter agrees with the past, and the degree of probability will be in an exact proportion to the circumstances in which they agree.

* Hartley on Man, Prop. 38.

Thus

Thus we see memory furnishes the materials for the judgment; the conclusions drawn partake much of the nature of invention. In this the two faculties in a manner meet; and for this reason I conclude they are radically the same, only differently exerted. Reasoning is a chain of judgments founded one upon another. It is the arithmetic of words.

Chap. VIII.

OF WORDS.

Abstract and general Terms.—Uses and Abuses of Words.—Thinking in Language.

WORDS were adopted as the signs of ideas, which are images of things; they are a sort of coin current among men to transfer their thoughts to one another *. Words serve likewise to represent collections of ideas, as is the case in general terms.

On examining the principles of language, it appears, that the first words of every language relate immediately to things, their properties or actions. Men in a very rude state of society, have little use for abstract or general reasoning. All our adverbs, conjunctions, and prepositions, were originally verbs or † substantives.

To number would be extremely difficult without words: they serve to distinguish numbers, of which we could have no distinct visible or tangible ideas. The nicest observer cannot have a distinct idea of

* 'Words, in all men's mouths (that speak with any meaning) stand for the ideas which those that use them have, and which they would express by them. Thus a child that takes notice of nothing more in the metal he hears called gold, than the yellow colour, calls the same colour in a peacock's tail gold; another, that has better observed, adds to shining yellow, great weight; and then the sound gold stands, when he uses it, for a complex idea of a shining yellow, and very weighty substance.'—Locke, b. iii. c. 2.

† See Mr. Horne Tooke's Epea Pteroenta; unquestionably the first work on this subject in our own or any other language.

ninety-

ninety-nine, and another of an hundred, but by the words.

When we obſerve any quality, or ſet of qualities, that are connected with ſeveral different objects, we conſtitute thence an abſtract word, ſuch are *roundneſs, whiteneſs, human nature*, &c.

General terms are formed, by obſerving that there are ſome qualities in which certain things agree, though differing in others; we rank, therefore, all the objects ſo agreeing under a general head, or claſs them. Theſe general terms do not excite any idea unleſs a particular one. Thus, if by the word *man* any idea is excited, it muſt be that of a particular man. The word animal is ſtill more general, yet if any diſtinct idea accompanies it, it is only that of a particular animal. In this caſe, however, there is no danger of confuſion, if the general term is well underſtood, that is, if the particular qualities to which it is meant to refer are defined, and diſtinctly pointed out, then any man or any animal will ſerve completely to repreſent the whole claſs in thoſe agreeing qualities, which the general term ſerves to expreſs *. It is manifeſt this is a refinement of human invention, to prevent the inconvenience of conſtantly referring to proper names, which would be almoſt as laborious as the contrivance of Swift's philoſophers, to converſe without words, by bringing the thing ſpoken of within ſight of the parties.

The general terms repreſenting *mixed modes*, ſuch as *parricide, virtue*, &c. have only to be defined in the ſame manner, by pointing out the actions or qualities

* In the whole buſineſs of genera and ſpecies, the genus, or more comprehenſive, is but a partial conception of what is in the ſpecies, and the ſpecies of what is to be found in each individual.—See Locke, b. iii. c. 6.

they are defigned to reprefent, and there will be no danger of confufion or miftake.

Words reprefenting complex ideas, which are objects of our fenfes, are defined by enumerating the fimple ideas of which they are compounded.

Words reprefenting fimple ideas cannot properly be defined, for it is impoffible to analyze the idea *white*, *fweet*, &c.

It is unneceffary to fay any thing of the nature and ufe of thofe words called particles. Such a difquifition would be better adapted to a grammatical treatife, than to the prefent work.

Words may pervert our reafoning, either through paffion or ignorance. As words, by being connected with objects, become in fome meafure capable of exciting pleafure and pain, fo they may contribute to prejudice us for or againft an object, when frequently united with it, as is evident in the ufe of the epithets good, fine, elegant, frightful, bad, &c *.

Whatever difputes or mifconceptions arife from ignorance of words, they generally happen in the names of *mixed modes*, or abftract general terms; for in the ufe of thofe words, which only reprefent complex

* "It ought to be remarked, that the words and phrafes of the parents, governors, fuperiors, and attendants, have fo great an influence over children, when they firft come to the ufe of language, as inftantly to generate an implicit belief, a ftrong defire, or high degree of pleafure. They have no fufpicions, jealoufies, memories, or expectations of being deceived or difappointed; and therefore a fet of words expreffing pleafures of any kind, which they have experienced, put together in almoft any form, will raife up in them a pleafurable ftate, and oppofite words a painful one. Whence it is eafy to fee, that the fine language expreffing praife, and the harfh one expreffing difpraife, muft inftantly put them into a ftate of hope and joy, fear and forrow refpectively.—Hartley, Prop. 47.

ideas

ideas of ſenſation, there can ſcarcely be any miſtake. The miſtakes alluded to uſually happen, 1ſt. From an idea being omitted, which ought to have been comprehended in that definition of a general term, which every man makes in his own mind. As in *chance-medley*, *man-ſlaughter*, *murder*, the *principal* idea is the ſame, yet the reſpective words ſuggeſt an idea materially different. 2ndly. From ideas being admitted, which ought not to be comprehended in the general term. 3dly, From an obſcure or confuſed view of the meaning. 4thly, Diſputes often ariſe, becauſe a man may have a part of the ideas, which are comprehended under the general word, more ſtrongly aſſociated with his other ideas than the reſt; of courſe he will have a partial view, and his reaſoning will be biaſſed by a kind of prejudice.

The firſt end of language is to make known our thoughts to others, in which we fail, 1ſt, When we uſe words without clear and diſtinct meanings; 2dly, When we apply received names to ideas, to which the common uſe of language does not apply them; 3dly, When we apply them unſteadily.

The ſecond end of language is to make known our thoughts with as much eaſe and quickneſs as poſſible, and this men fail in when they want either names for complex ideas, or abſtract and general terms. The third end of language is to convey the knowledge of things, and this cannot be done, but when the ideas agree with the reality of things *.

Other abuſes of language, not noted above, are, 1ſt, Affected obſcurity; 2nd, Taking words for things, as *abhorrence* of a *vacuum*, *ſubſtantial forms*, &c. to which I may add, taking *memory*, *judgment*, *imagination*,

† See Locke, b. iii. c. 9.

for diftinct powers, and almoft for diftinct beings, inftead of what they really are, only different modes of the mind's acting; 3dly, Figurative language.

The frequent ufe of abftract and general terms makes us think in language more than we otherwife fhould do; yet it is feldom that a chain of thought is carried on in a regular chain of words, as if we were explaining our thoughts to another, unlefs indeed when we con over a fpeech or any tranfaction where language is immediately concerned.

CHAP. IX *.

OF PLEASURE AND PAIN.

Pleaſure in conſequence of Action.—By Aſſociation.—By Paſſion.—Utility.—Surprize.—Variety.—Regularity.—Imagination.

"TO excite us to the actions of thinking and motion (ſays Mr. Locke) the author of nature has joined to ſeveral thoughts and ſenſations a perception of delight; without this we ſhould have no reaſon to prefer one thought or action to another, motion to reſt; in which ſtate man, however furniſhed with the faculties of underſtanding, &c. would be a very idle inactive creature, and paſs his time only in a lethargic dream. Pain has the ſame effect (continues he) to ſet us on work that pleaſure has; ſince we are as ready to avoid that as to purſue this."

It is evident that pain and pleaſure are relative terms, expreſſive of an alteration in the ſtate of the perſon, bodily or mental. 1ſt. Some degree of pleaſure or pain attends almoſt every impreſſion on the five ſenſes. 2dly. Relief from an uneaſy ſituation is pleaſure; thus, the wants conſequent on our natural appetites are painful, and to ſatisfy them pleaſant †. 3dly. The recollection of the ideas of thoſe things which are hurtful

* At this chapter the ſecond part of this book commences, or that which treats of the active powers of man.

† The appetites, which are the ſprings of the paſſions, are, hunger, thirſt, and the deſire of procreation. The bodily affections productive of pain and pleaſure, and which are connected with the ſenſe of feeling, are, ſickneſs and wearineſs, and to theſe we may oppoſe the feeling of health and vigour, and the ſenſation of life, or the pleaſure attending the moderate action of our ſenſes.

to the body, or ideas aſſociated with them, is productive of trouble to the mind, and the contrary *, as will be amply proved in the progreſs of this volume.

So far is evident from experience. To aſcertain the nature and cauſe of painful and pleaſurable ſenſations is an inquiry of ſome difficulty. Anatomiſts and phyſiologiſts are, I apprehend, very generally agreed in one point; it will therefore be ſufficient to ſubjoin the opinion of one of the moſt eminent, eſpecially as the ſubject has been in part inveſtigated on a former occaſion †. 'All I ſhall aſſume (ſays Dr. Monro) is what is founded on experiments, that ſenſation and motion do depend upon the nerves; that ſenſations are pleaſant as long as the nerves are only *gently* affected, without any *violence* offered to them; but as ſoon as any force goes beyond this, and threatens a ſolution of union, it creates that uneaſy ſenſation, pain ‡.'

If we examine the courſe of human life, we ſhall find almoſt the whole of poſitive pleaſure to conſiſt in action of ſome kind. Sleep will hardly come under the denomination of poſitive pleaſure. It is deſired, becauſe it produces a relief from wearineſs, and is a ſtate to which our bodies naturally tend when fatigued; otherwiſe it is a ſtate of inſenſibility, and it would be an abuſe of language to call it pleaſure. Some impreſſions are primarily grateful and others diſagreeable. That the painful and diſagreeable are ſuch by an intenſe degree of agitation, which ſtrains and prejudices the organs of ſenſe, is probable. It is alſo probable, that the agreeable follow the general law of our nature, and are pleaſing on account of the gentle yet lively action

* The expreſſion of pain in the countenance is much the ſame whether *bodily* or *mental,* only differing in the degree.

† See book ix. c. 36.

‡ See alſo Cheſelden's Anatomy, chap. Nerves.

or agitation excited in us. There will remain little doubt of the truth of this doctrine, if we consider that light and heat in a moderate degree are productive of pleasure, and in greater quantities hurt by their intenseness; that many acids, &c. which, when diluted, are agreeable to the taste, are highly painful when applied pure and unmixed *. In fine, absolute rest is the death of sense. Motion is the very characteristic of animal life: and most of our intellectual as well as sensible pleasures seem to depend on a moderate increase of action. Recalling an old idea, which is connected with a train of other ideas, is manifestly pleasing; and this appears to result from the gentle agitation imparted to the organs of thought. "The music was like the memory of joys that are past, mournful, but pleasant, to the soul." The pleasures of the imitative arts, of figurative language, of the sublime, the beautiful, and still more, the pleasures of variety, will meet an easy solution on this principle †.

Of pains, some are positive, as really affecting the body ‡, others only affecting the mind by being connected

* "There is no one, of ever so little understanding in what belongs to a human constitution, who knows not, that, without action, motion, or employment, the body languishes; and is oppressed, &c." "In the same manner the sensible and living part, the soul or mind, wanting its proper and natural exercise, is burthened and diseased," &c.

Shaftesbury Enq. Con. Virtue, b. ii. p. ii. s. 1.

† This is to be understood, however, as nothing more than an attempt to account for the nature of pleasure and pain; and, I own, it appears to me the most rational I have seen. The establishment or rejection of this doctrine will not affect the truth of my general principles; and I can start fairly with this self-evident maxim, that pleasure and pain are the effects of certain impressions on all our senses, and that the cravings of the appetites are painful, and the gratification of them administers pleasure.

‡ "Since the pains of feeling are far more numerous and violent than those of all our other senses put together, the greatest part

nected with painful ideas; and further, pain is generally consequent on the absence, or deprivation of pleasure; that is, our expectations are disappointed, and we are robbed of the pleasure of hope, for we are ever in pursuit of pleasure; but the pain is always greater in proportion as the expectation was probable. Thus, there are many sounds, which, though very dissonant, scarcely give us pain; yet to a good ear the smallest dissonance in music is offensive. The same may be observed in painting, architecture, &c.

Our ideas flowing naturally in a train, whatever is introduced forcibly, and bearing not an immediate connection, pains the mind, because it distracts it with the variety of ideas, which are crouded together by the collateral circumstances introduced by it, as well as those depending on the former train of thought.

An impression, which was painful, will leave a trace or idea of pain behind it, and a pleasurable impression an agreeable idea; these, it is plain, may be excited by any of the associated circumstances. But the strongest relation is that of causation. What we conceive to be the cause of painful or pleasurable sensations will be intimately combined with those ideas; and hence we always love or hate most vehemently what we conceive to produce pleasure or pain. But as the principle of association is not confined to the relation of cause and effect alone, any other circumstance associated by contiguity of time or place, or even by resemblance, will partake of the passion. It is well known that the very word physic conveys a disagreeable idea to children, who have been compelled to take nauseous draughts, and they can scarcely endure the person of the apothecary. The mention of parti-

part of our intellectual pains are deducible from them.—*Hartley on Man*, Prop. 13.

cular medicines will sometimes excite vomiting in very delicate and irritable habits. Some medicines, palatable in themselves, from the idea of their painful effects, we nauseate.

The sensible pleasures are greater in number than the sensible pains. Of this, waving any abstract reasoning, such as the love of life, and the pleasures of habit, any man may be convinced, who will be at the trouble of enumerating them. Now our intellectual pleasures and pains are combinations of the sensible, and of course our pleasures will be more numerous than our pains. Ideas seem to have an effect on the mind similar to what some applications are said to have on the body, which are sedatives when applied in large quantities, and stimulants in small. "The sight of tortures chills the whole soul, and produces almost a total stagnation of thought *;" but relations of tortures have never any such effect, and men seem to find them agreeable, by the avidity with which they listen to them. The truth is, a very violent mental agitation is required to produce pain, and every moderate agitation will produce pleasure: a proof that the intellectual pleasures must be very numerous, and the intellectual pains very few. A description of a storm or battle, which is really composed of painful or disagreeable ideas, will excite in very few a degree of agitation which arises to pain, and most people experience an actual pleasure from these descriptions. The very deformities of nature, a rugged and frightful hill, or a storm of lightning, give us pleasure, when exactly copied; and we read with pleasure even of ill actions: and see the cruelties of tyrants represented on the the-

* Gerard on Genius, part ii. s. 4.

atre,

atre, with a kind of solemn delight*. This can only result, 1st, From the mental agitation, which these trains of thought produce. 2dly, From some agreeable ideas, which may be connected with the train of thought; for the mind is ever ready to turn and embrace pleasing associations, and seldom fond of pursuing a disagreeable train. 3dly, Variety is generally connected with rude nature, and imperfect characters.

The pleasure resulting from narratives of apparitions, enchantments, &c. may be accounted for on the same principles; and from the pleasure attendant on them results the easy belief which men afford to such fancies.

The pleasure of *utility* results from the ideas of pleasure that are associated with the ends of any work or undertaking. Hence these pleasurable ideas become associated with the employment itself. Though in some instances this effect may be counteracted †, the general principle holds nevertheless true.

Pleasure

* At the subsiding of grief there is a certain melancholy pleasure. A distant view of the misfortunes of others affords a similar sensation: but they produce pain if they touch us nearly; and some hearts are so susceptible, that they are moved much easier than others. On the imagination being excited to action, we feel a most agreeable sensation; and it is a common maxim among authors, to leave something to the imagination.

† "A prison is certainly more useful to the public than a palace; and the person who founds the one is generally directed by a much juster spirit of patriotism than he who builds the other. But the immediate effects of a prison, the confinement of the wretches shut up in it, are disagreeable, and the imagination either does not take time to trace out the remote ones, or sees them at too great a distance to be much affected by them."—*Smith's Theor. Mor. Sent.* part i. s. 3. c. 3.

"On the contrary, we may add, the pleasure, the gaiety, the greatness of those who inhabit the palace, naturally affect the mind with pleasing sentiments.

"Trophies

Pleasure may result from *surprise* on several accounts. The agitation which a moderate surprise occasions is agreeable; but the surprise which is united with the satisfaction of finding ourselves safe, after fancying we were in danger, is still more exquisite; and, perhaps, the most exquisite of all is, when we find occasion for self-commendation, as in solving a problem, &c.

The pleasure of *variety* seems to be the effect chiefly of the moderate, and yet lively agitation, which several trains of thought induce.

Though it appears from all that has been said, that gentle agitation is in general productive of pleasure, yet the mind has likewise a natural love of ease, and will not bear much fatigue; a little exertion soon tires it; for this reason, regularity is pleasing, and the contrary. We readily embrace a regular figure; the train of thoughts flow naturally to the different parts; we comprehend it; our mind is satisfied with it. We pursue, with a kind of easy emotion, a regular series; and hence it is, that men have been so fond of reasoning from universal axioms. The irregular pleases in

"Trophies of the instruments of music or of agriculture, imitated in painting or stucco, make a common and an agreeable ornament of our halls and dining-rooms. A trophy of the same kind, composed of the instruments of surgery, of dissecting and amputation knives, &c. would be absurd and shocking. Instruments of surgery, however, are always more finely polished, and generally more adapted to the purposes for which they are intended, than instruments of agriculture. The remote effects of them too, the health of the patient, is agreeable; yet as the immediate effect of them is pain and suffering, the sight of them always displeases."—*Ib.*

"Instruments of war are agreeable, though their immediate effect may seem to be, in the same manner, pain and suffering; but then it is the pain and suffering of our enemies, &c. With regard to us, they are immediately connected with the agreeable ideas of courage, victory, and honour."—*Ib.*

the

the works of nature from custom, and the ideas connected with them. Nevertheless, where the end is pleasure, we may lay it down as an universal rule, that an object ought to possess some degree of variety without entirely departing from that uniformity we love.

The pleasures of the imagination I have asserted to be much more numerous than the pleasures of sense; and these result, first, from whatever of the beautiful is possessed naturally by the objects described. 2dly, From the associations of pleasure originally deduced from the senses with other ideas.

CHAP. X.

OF LOVE AND HATRED.

Definition of Love.—Origin of the Social Paſſion.—Diſlike and Hatred.—Deſire and Averſion.

LOVE is the idea of pleaſure aſſociated with another idea. Some of the firſt impreſſions of pleaſure an infant receives are by the gratification of its appetites. Its firſt emotions of love are, therefore, towards the being that ſupplies it with food, &c.; and it is obſervable, infants never fail in this love. The idea of pleaſure is in reality firſt united with the food itſelf, and of courſe transferred to it, and thence to the object by whom it is ſupplied. All our wants are ſatisfied (particularly in our tender years) by means of our own ſpecies; hence the moſt agreeable ideas are united with them, and ſo often repeated, that in time the love of mankind becomes, in a manner, a neceſſary part of ourſelves; and from this ſource may proceed the ſocial affections.

Diſlike and hatred are the oppoſites to love, and reſult from the idea of pain combined with another idea. A child ſhall have no diſlike to a certain medicine, till after it has produced nauſea, or ſome painful ſenſation, and thenceforward he will ſcarcely hear it named without expreſſing his averſion *.

The paſſions have been analyzed, and thus reduced to *love* and *hatred* by ſome of the oldeſt writers on the

* The idea of pleaſure being annexed to a thing, conſtitutes it, as we ſay, good. The idea of pain (either immediate or related) evil. "Theſe (as Mr. Locke obſerves) are the hinges on which the paſſions turn." See Locke, b. ii. c. 20.

ſubject

subject now extant. It is evident, that *desire* and *aversion* are the same passions made active. Inanimate things may be the objects of love or dislike. "The house which we have long lived in, the tree whose verdure and shade we have long enjoyed, are looked upon with a sort of respect *." The Dryads and Lares, a sort of genii of trees and houses, were probably first suggested by this kind of affection.

Desire or the sensation of want, may be either sensual or imaginary; it may be fixed on the pleasure of gratifying an appetite, or on the delight accruing to the eyes or ears from the perception of beauty. When instruction, education, or prejudice of any kind, raise a desire or aversion towards an object, it must be founded on an opinion of some quality, for the perception of which we have the proper senses. Thus, if beauty is desired by one, who has not the sense of sight, the desire must be raised by some apprehended regularity of figure, sweetness of voice, smoothness, or softness, or some other quality perceptible by the other senses (without relating to the ideas of colour †) or from the commendation of others.

* Smith's Theory Mor. Sent. part ii. s. 3. c. 1,

† Hutcheson.

CHAP. XI.

OF BEAUTY.

Of Beauty in general.—Original.—From Association.—Nature and Art.

WE may ſay in general of beauty, that it is ſome quality in objects capable of exciting unmixed ideas of pleaſure, independent of the gratification of any of the animal appetites. This definition does not differ much from that of Plato, "Το δι οψεως και ακουης ηδυ *." Perhaps we give this pre-eminence to the pleaſures not depending on appetite, as they are the moſt innocent, and leaſt liable to diſguſt and ſatiety †.

The principal diſtinction between the pleaſure afforded by ſublime objects, and that by thoſe which we term beautiful, ſeems to be, that the latter is pure unmixed pleaſure from the gentle agitation, whereas the former borders upon pain (ariſing from ſome compound of the paſſion of fear) and is often not unmixed with actual pain, and always requires a greater exertion, and produces a more violent agitation of the organs of ſenſe.

* "The pleaſant to the ſenſes of ſight and hearing."—Plato, Hippias major.

† Ib. Beauty is never properly applied to the ſenſe of taſting, as it ſeems too coarſe an enjoyment to be reckoned among the rational ones.

The

The pleaſure afforded by riſible objects * is not that tranquil pleaſure which ariſes from the contemplation of beauty, neither is it pure or unmixed pleaſure. Contempt, or ſome painful paſſion, is generally in ſome degree compounded with the riſible idea.

The primary conſtituents of beauty ſeem all of them to be ſuch as promote gentle agitation, and thus increaſe our ſenſe of life. Such are, 1ſt, Lively colours, where they are not ſo ſtrong, or the application ſo continued, as to produce pain †. The young man couched by Cheſelden thought ſcarlet the moſt beautiful colour, and of others the gayeſt gave him moſt pleaſure. The firſt time he ſaw *black* it gave him great uneaſineſs ‡. 2dly, Variety and contraſts of colours, where the tranſition is lively, without being too abrupt. Females of taſte make much uſe of this principle in the choice of their ornaments of dreſs. 3dly, Certain ſounds and combinations of them, analogous to thoſe

* Riſibility is often productive of pleaſure, as are ſome other affections which have no relation to what is called beautiful. Beauty ſeems moſt properly applied to a pleaſing idea excited by ſome external object; but moſt frequently our ideas of beauty ariſe from aſſociations, as the ſenſe of propriety, eaſe, &c. &c.

† "It is evident that gay colours, of all kinds, are a principal ſource of pleaſure to young children; and they ſeem to ſtrike them more particularly, when mixed together in various ways."—Hartley on Man, Prop. 22.

"In adults the pleaſures of colours are very languid in compariſon of their preſent aggregates of pleaſure formed by aſſociation.—Ibid.

Green, the middle colour of the ſeven primary ones, is moſt grateful.

‡ Cheſelden's Anatomy, p. 301. The boy couched by Cheſelden was moſt pleaſed with *red*, perhaps, becauſe it was the completeſt exertion of his newly acquired faculty. He dreaded *black*, probably, becauſe it reſtored him to his former ſtate, and was in fact a partial negation of ſenſe.

of colour juſt mentioned. 4thly, Flowing eaſy motion, without that violence which gives a double ſenſation of pain, viz. beſides the harſh effect to our ſenſes, an aſſociated pain, by putting ourſelves in the place of the object. 5thly, The agitation which a water-fall, a varied proſpect, or an high aſcent, produces, may be a ſource of that kind of pleaſure we aſcribe to beauty, even independent of the aſſociated ideas. Hence it follows, that figures, which poſſeſs variety without any thing harſh or abrupt, the waving line, running water, and many of thoſe conſtituents of beauty remarked by painters, are naturally and primarily ſuch. Theſe when ſo diſpoſed as not to contradict any attachment eſtabliſhed by cuſtom, and ſtill more when they coincide with it, as when nature is imitated in a fine landſcape, or deſcribed in a poem, never fail to give pleaſure; and hence it appears, that authors have miſtaken who have deſcribed that which is moſt fit and regular as the moſt beautiful. Admitting, in the inſtance adduced by Plato *, that the wooden ſpoon might be moſt uſeful and proper; yet if even the value is ſet aſide, I apprehend the golden one would be allowed to poſſeſs the moſt intrinſic beauty.

The aſſociations that ariſe originally from the pleaſures of ſenſe may become ſo diſtant, that we loſe ſight of their origin; and to an object in this caſe conveying pleaſure, men univerſally aſſign the epithet beautiful. Though it is probable, that moſt frequently ſome of the primary conſtituents of beauty will be compounded with it, and of this mixed nature are moſt of the objects we denominate beautiful, as a fine houſe, a landſcape, a running horſe, &c. On this account it is worth obſerving, we often find a whole to poſſeſs

† Hippias Maj.

beauty, which by no means resides in the constituent parts *. The simple constituents of beauty have but little influence when put in competition with the desire of gratifying the appetites, or the fear of pain; to illustrate this, I shall only mention a universal and common prejudice. There is nothing really deformed in serpents; on the contrary, many of the acknowledged constituents of beauty, such as lively colours, variety, &c. are found in them; yet from a knowledge of their noxious properties we cannot by any means bring ourselves to view them with that pleasure which beautiful objects ought to inspire. An object which is beautiful will impart a virtue to every thing connected with it. Things preposterous and deformed in themselves are reconciled to us when worn by a beautiful person; and hence fashion derives its extensive influence. On the contrary, what is worn by rustics is lessened in our estimation by the awkwardness of the wearer. Men admire the very defects of their mistresses, and often judge of beauty by their peculiarities.

> "Amatorem quod amicæ
> "Turpia decipiunt cœcum vitia aut etiam ipsa hæc
> "Delectant; veluti Balbinum polypus Hagnæ †."

Hence we may in a great measure account for both the uniformity and diversity of taste prevalent among mankind. There are some objects and qualities, which interest and are pleasing to every man; others, with men differently circumstanced, receive a colour from other ideas, with which they may be connected. The human form is the most pleasing of all forms to every

* Hippias Maj. ad. fin.

† The robe of magistracy, even when seen on the stage, is accounted elegant and respectable, and suggests correspondent ideas.

man, becauſe from ſociety he has derived all his choiceſt pleaſures; but whether white or black is to be preferred, whether an aquiline or a flat noſe, will, perhaps, depend on early aſſociations to determine.

The influence of aſſociation over our ſenſe of beauty is further obvious in this, that ſcarcely any man exiſts, who does not annex to particular ſets of features good and bad moral ideas; and theſe will probably be drawn from particular perſons. I knew a celebrated painter, whoſe beſt hiſtorical figures all bore ſome reſemblance to himſelf; and others have been known, who conſtantly copied their own wives as the perfection of beauty.

Rural beauties are ſo compounded of the primary conſtituents of beauty, united with ſo many things that gratify our appetites and ſenſes, together with many complex pleaſures, ſuch as ſports and paſtimes, the amorous pleaſures, &c. that it is no wonder theſe, with the encomiums of others, which have always an influence on imitative animals, ſhould make them the almoſt unceaſing theme of poets. Of the beauties of art I ſhall treat in another chapter.

Chap. XII.

OF CUSTOM.

Pain from Custom.—Pleasure.—Admiration.

TWO observations naturally occur, when we contemplate the force of custom: 1st, That when we have been long used to see two things together, we do not with perfect pleasure endure to behold them separate. This is, in truth, a species of disappointment. The idea appears incomplete; there is a want, and a painful sense of want. Thus a cow with but one horn, or a dog with one ear, is a disagreeable object, though, doubtless, if they had been created with but one, two would have been accounted a deformity.

2dly, It is commonly remarked, that custom will make us love almost any thing, and will reconcile us to almost any condition. The force of custom here seems to depend entirely on the principle of association. We have already seen that pleasures are more abundant than pains. There is, therefore, scarcely any state in life, which will not be productive of many agreeable ideas; these ideas become connected with the objects and actions which have occurred, while they have remained impressed upon the mind; the idea, therefore, that imparted the pleasure, and the other idea, will become blended together; nay, the sense of pleasure will be transferred from the former to the latter, so that it may recur united with a sense of pleasure, even when the object that originally imparted the pleasure is forgotten. Thus it is not at all uncommon

to

to hear perſons ſpeak in rapturous terms of their paſt ſituation, when it is impoſſible for them to recount the reaſons why it was ſo agreeable; or, if they were to attempt to recount them, they would probably not aſſign the true cauſes. Actions and things in themſelves indifferent thus borrow pleaſures from others, and by this means attach us to them, as we have ſeen that faſhions, without any one original principle of beauty, nay, even deformed in themſelves, obtain reſpect and admiration from the beauty of the wearer.

It is thus that card-playing, and ſome other habitual vices, not in themſelves pleaſant, acquire an empire over us. The deſire of imitating others has, we will ſuppoſe, been our firſt motive for engaging in them; they have been united in the courſe of our purſuing them with the pleaſures of ſociety, the occaſional gratification of avarice, the pleaſure of ſurpriſe, &c. and thus afterwards appear pleaſant themſelves from their borrowed luſtre.

Whether the love of life itſelf is an innate principle has been diſputed; for though infants fear pain, yet they have no apprehenſion of death, till reaſon has ſo far made a progreſs, as to inform them that it is connected with pain, and life with happineſs. The love of life is generated from the ſenſe of pleaſure reſulting from the goods we poſſeſs in it; and this affords no inconſiderable proof that the good in the world overbalances the evil. So ſtrongly, indeed, are the ideas of life and happineſs aſſociated, that moſt men would rather live miſerable, than not live at all: thus again we ſee that an aſſociated affection may overcome and counteract the natural affections, and even thoſe that gave it birth.

It will be unneceſſary to add any more in this place on this ſubject, or to endeavour to prove more at large

the influence of custom. To an attentive reader, many facts throughout the remainder of this work will occur to confirm it, and almost all that has been said of a sense of beauty derived from association will apply likewise to moral beauty *. It is observable, that every nation and every age has a fashion in thinking as well as in dress; and the whole cast of thinking will be more uniform than men usually suppose. The sports of nations partake of the nature of their government, and their political prejudices and interests. Gladiators and mock battles were the favourite amusements of the warlike Romans.

Men love what is uncommon at first, because what produces mental agitation produces pleasure; and there is no passion produces so much mental agitation within the limits of pleasure as admiration; they afterwards expect a renovation of that pleasure, which was only the effect of surprise; and often the very recollection of that pleasure will keep alive the passion.

* "In the reign of Charles II. a degree of licentiousness was deemed the characteristic of a liberal education. It was connected, according to the notions of those times, with generosity, sincerity, magnanimity, loyalty, and proved that the person who acted in this manner, was a gentleman, and not a puritan."—Smith's Th. M. S, pt. 6. s. 2.

In the same manner as you are induced to love and imitate whatever is connected with a pleasurable or beautiful object, you will endeavour to avoid what is connected with pain or deformity. Hence men often act in extremes. Lord Bolingbroke asserted, that what first gave him a distaste to religion, was the puritanical severity in his own family.

CHAP. XIII.

THE PASSIONS.

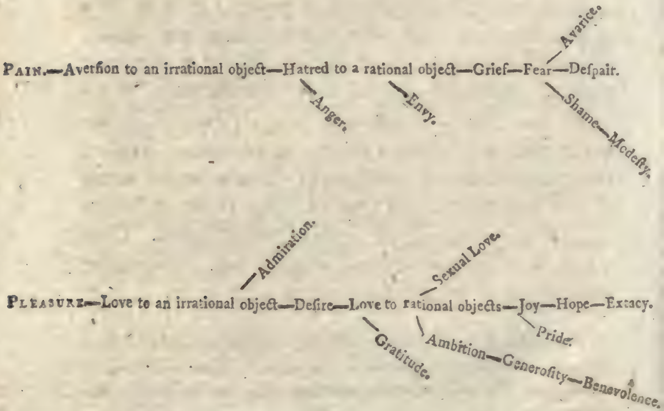
Of the Passions in general.—Particular Passions.—Associated Passions.—Paternal Love.—Sympathy.—Avarice.—Ambition.—Love.

IT may prove of the higheſt importance in morals to analyze the ſeveral affections and paſſions. The general cauſe has been already traced to the ſimple ſenſe of pleaſure and pain; we have ſeen further what it is that is called a ſenſe of beauty *; and now, from the ſeveral modifications and combinations of theſe, we ſhall, perhaps, be able to form at leaſt a conjecture how other more complex paſſions come to be formed.

Love having been proved to proceed from an idea of pleaſure combined with another idea, and *diſlike*, or hatred, from an idea of pain combined in the ſame manner; *deſire* and *averſion* have been ſhewn to be no other than theſe paſſions more actively exerted. Love in the extreme, without deſire, is *admiration*. Deſire, when applied to the gratifying of certain natural wants of our bodies, is called *appetite*. *Joy* is the poſſeſſion of a thing loved, a lively ſenſe of preſent good. *Grief* is a ſenſe of diſappointment, or good loſt. *Fear* is the ſenſe of pain, or averſion, united with grief. *Anger*

* Hartley denominates the paſſions, "aggregates of the ideas, or traces of the ſenſible pleaſures and pains." How they become united into the moſt common affections it is our buſineſs to explain.

is an extreme of averſion, united with a deſire of removing the object. *Revenge* is a continuance of anger. *Envy* is anger excited through the deſire of poſſeſſing what another man is poſſeſſed of. *Hatred* is the continuance of envy or reſentment. *Hope* is a mixture of deſire and joy. *Pride* is ſelf-ſatisfaction, and is to ambition what joy is to deſire. *Contempt* is a low degree of hatred or averſion, without any mixture of anger or of envy. *Curioſity* is deſire excited by the natural love of action, often ſtimulated by appetite, or quickened by the love of beauty. *Shame* is fear ariſing from the ſocial affections; that is, a fear of having done ſomething that may leſſen us in the eſteem of others; it is the oppoſite of *Vanity*. *Deſpair* is nothing but an exceſs of grief. Perhaps the annexed ſcheme may contribute to elucidate the progreſs of the paſſions.



There is ſcarcely any ſuch thing as a ſimple paſſion; even thoſe which I have here ſpecified are generally compounded with each other. Whatever ideas are predominant will determine the bent of the paſſion, much depending on the peculiar tone of the organs at different times. Some paſſions more eaſily mix than others.

Paſſions naturally terminate, when their end is accompliſhed. This, however, does not happen in all caſes. It was remarked, that an impreſſion, as it is more vivid, remains proportionably longer on the organ of ſenſe; all the component ſimple parts of it are more ſtrongly impreſſed, and it is aſſociated with a greater number of ideas. Impreſſions accompanied with pain or pleaſure are more vivid in proportion to the degrees of pain or pleaſure, and ſuch we muſt remember are all paſſions. Theſe impreſſions and ideas are of courſe more vivid than any others, of courſe aſſociated with a greater number of ideas, all of which will ſerve to recall them, and thus a paſſion becomes the cauſe of its own continuance, and by this means influences our train of thinking.

From what has been ſtated it appears, that paſſions are transferable from one object to another. An idea being often repeated with an idea which we love, and which of courſe gives us pleaſure, we come at laſt to love the idea which was at firſt indifferent. What is more common than to love the children of thoſe whom we eſteem, and that for no merit or beauty in the children themſelves? In parental love, the paſſion is in part transferred from ſelf to the offspring. The mother, during her pregnancy, connects the idea of the infant in her womb with a number of agreeable ideas, with pleaſure and with hope; hence maternal love is ſtronger at firſt than paternal. The idea of duty,

duty, and the example of others, tend to increaſe the paſſion; afterwards cuſtom, and the little cares about them. It is obſervable, that the love of parents is weak at firſt; but love ruſhes in by little aſſociations as from a thouſand ſources.

On this principle depend ſome of the ſtrongeſt affections that ſway the human race. Every deſire, for inſtance, is attended with a degree of uneaſineſs; to remove it, therefore, is pleaſure. Now, when men once perceive certain agreeable conſequences from obtaining an object, a deſire of obtaining it enſues; this deſire will be liable to be renewed, and will be renewed ſimply as a deſire, without any retroſpect to the firſt motives. This is evidently the caſe in avarice, where, dropping the immediate ſteps between money and happineſs, men form a connection, which does by no means naturally and immediately exiſt, and love the treaſure for its own ſake. The ſame might be obſerved concerning the deſire of knowledge, the delight of reading, planting, &c. Theſe were firſt entered on with a view to ſome farther end, but at length become habitual amuſements; the idea of pleaſure is aſſociated with them, when the firſt reaſon is quite vaniſhed out of our minds; nay, we find this power of aſſociation ſo great, as not only to tranſport our paſſions and affections beyond their juſt bounds, both as to intenſeneſs and duration, but alſo to transfer them to improper objects, and ſuch as are of a quite different nature from thoſe to which our reaſon had at firſt directed them *."

I ſhall cloſe this ſketch of the paſſions by a ſhort account of ſympathy or ſocial affection, and afterwards, by

* Preliminary Diſſertation to Law's Tranſlation of King's Origin of Evil.

by the hiſtory of thoſe moſt powerful incentives to action, avarice, ambition, and the paſſion of love between the different ſexes.

The pleaſures of ſympathy are generated, 1ſt, by that love to our fellow-creatures, which is the effect of early obligation *. 2dly, Becauſe the ſight of any enjoyment excites in us the pleaſurable ideas of that enjoyment, and unleſs envy interferes, theſe will ever have their due effect. Theſe feelings are increaſed by the praiſe that is beſtowed on benevolence, &c. and the hope of reward in another life. Sympathy in the misfortunes of others has a double effect; when beheld at a diſtance, as in theatrical repreſentations, I believe moſt men find ſomething rather pleaſing than otherwiſe in them, and this ariſes from the pleaſure that attends moderate emotion, even though derived from a painful ſource. In perſons of very delicate ſenſations, this affection often degenerates into actual pain; and on beholding real woe, it is ſuch to all who retain the common characteriſtics of humanity. Compaſſion, or the deſire of relieving diſtreſs, is no other than a wiſh of removing pain. The ſight of a wound excites immediately ideas of pain in our minds, and we feel a ſenſation of the ſame nature (though weaker) according to our memory of ſimilar pains, or, as we by deſcription judge of them, from the pains that we really have felt. To relieve diſtreſs, therefore, is actually taking off pain from ourſelves; to the act of relieving we give the name *generoſity*. The idea of the pleaſure is afterwards excited by hearing of an act of generoſity, nay, is aſſo-

* The ſocial pleaſures and affections may, as Dr. Hartley obſerves, be much indebted for their increaſe to the pleaſures of the palate. Since it has been cuſtomary in all ages to ſatisfy our appetites in the company of our neareſt connections, the idea of pleaſure will become combined with them.

ciated with the very word itself, the mention of which, I believe, in most people, excites a grateful sensation. By these means, the virtue of sympathy may be constantly maintained, and every amiable passion cherished.

It has been already intimated whence the passion of avarice derives its origin. The natural wants of man, it is true, are very few; yet in the present state of society, these wants are not to be supplied without some exertions on our own parts. The first design, then, of human beings, is, to acquire such a competence as will satisfy the calls of nature. But observe what habit does. By a continued pursuit, we grow eager in the chace; the first object is lost sight of; we annex the idea of pleasure to the means or the instruments, and fancy riches to have something in themselves desirable. A passion different from the first is now generated; one man's example imparts fresh vigour to another, and the end of life is forgotten in the ardour of an imaginary pursuit *. When the idea of pleasure is once transferred thus to the instrument, we see a child prefer a piece of money to many actual gratifications that might be enjoyed immediately. I knew a covetous man, who hired a very uncomfortable large house, a third part of which he did not inhabit, because he thought it a good bargain to procure an house of that size at the same rate as a smaller. The same man left a pleasant farm and a good estate, and bought a commission in the army, purely because he could procure it at a *cheap* rate.

" Avarice is checked, 1st, By the strong desires of young persons, and others, after particular gratifications. 2dly, By considering the insignificance of riches in warding off death and diseases, also shame and con-

* " Et propter vitam, vivendi perdere causas."—Juv.

tempt

tempt in many cases; and in obtaining the pleasures of friendship, religion, &c. 3dly, By the eager pursuit of any particular end, as learning. fame, &c *." We may observe, that avarice is only the passion of little minds, and will be chiefly predominant in uncultivated persons, whose attention cannot be drawn from it by nobler pursuits; and in old people, whose sensual passions are decayed.

Ambition seems to be founded, 1st, On the hatred or aversion to poverty, and all its concomitant disadvantages and inconveniencies. 2dly, On the experience that we are indebted to our fellow-creatures for many conveniencies of life; and from the habit generated even in children, of endeavouring to please them, in order to obtain many objects of pleasure to our senses. 3dly, Many of the constituents of natural and artificial beauty are possessed by those in high stations, we therefore annex pleasurable ideas to those stations, and love them on that account. 4thly, Custom, and the words usual in commendation, being applied to such persons, increase the passion.

Ambition will take a different course, according to the disposition or cast of thinking in different persons. Thus if a man is habitually sensual, his ambition will still have an inclination towards what may gratify his appetites. One man, perhaps, from education or example, has acquired a habit of admiring fine cloaths; another, from natural timidity, avoids shame and poverty. Commonwealths promote ambition of a different kind from that which is prevalent in monarchy. Ambition takes a different course, according to the time of life. It is to be remarked, that the primary constituents of this passion (as indeed in all others) will be obscured sometimes by the associated affections.

† Hartley, prop. 48.

The

The praiſe beſtowed on the heads of certain ſects of philoſophers, led many men to deſpiſe the natural objects of ambition, riches and pomp; and the natural diſlike to poverty and dirt was ſubdued and forgotten.

The paſſion of love (and eſpecially between refined perſons) is of a very complex nature; and far removed from the ſenſual appetite, with which it is ſometimes even very ſlightly connected. It is a well known fact, that an accompliſhed woman of fortune and family eloped ſome years ago with an Italian eunuch, whom ſhe married for love. The truth is, that beſides the appetite, the ſocial paſſion, as before explained; and this, heightened by the protection a weaker perſon ſeems to claim from us; the ſenſe of beauty; admiration of particular accompliſhments; the reſpect due to high birth or fortune; the commendation of others, and habit, in many reſpects concur more or leſs to form the paſſion.

Men of the world are all of them ſenſible what ſucceſs may be derived from a pleaſurable ſtate of mind, in which the object, whom they wiſh to pleaſe, may happen to be. On this account they ſtudiouſly mingle in all the pleaſures and amuſements, of whatever kind, in which that perſon is found to delight. It is a maxim of Lord Cheſterfield, " Make a perſon in love with themſelves, and they are certain to love you in return *." The pleaſure of receiving gifts is directly connected with the object that beſtows them; where preſents cannot be made, praiſe and commendation are the ordinary means, and if their ſincerity is

* One of our comic writers preſcribes, that a man muſt firſt make a woman a friend before he ventures to appear as a lover.

not

not doubted, ſeldom fail of ſucceſs. I queſtion not, but it might almoſt ſecure the ſuit of a lover to be the meſſenger of ſome very agreeable piece of intelligence to his miſtreſs. Pleaſurable ideas, we know, are naturally connected with perſonal beauty, riches, high birth, great qualities, or fame. Some impoſtors, under the maſk of being perſons of rank, have inſinuated themſelves into the good graces of females; nor could the diſagreeable ideas naturally annexed to falſhood and deception, afterwards vanquiſh the attachment. In fine, if by any means a man can become the aſſociate of agreeable ideas, on the principles every where proved, I think, throughout this book, he may ſoon hope to obtain a part in the affections of his miſtreſs; and this may ſerve to account, in ſome meaſure, for the many whimſical connections we are every day witneſſes of.

"When Miſs delights in her ſpinnet,
"A fidler may a fortune get;
"A blockhead with melodious voice,
"In boarding ſchools may have his choice;
"And oft the dancing maſter's art
"Climbs from the toe to touch the heart;
"In learning let a nymph delight,
"The pedant gets a miſtreſs by't *."

There is no greater miſtake, than that the world is governed by motives of intereſt. Cool ſelf-intereſt acts in very few inſtances. Where mankind are not ſwayed by the natural affections, that is, by thoſe ideas with which pleaſure is naturally connected, they are generally determined by ſome prejudice, that is, an idea with which pleaſure or pain is fantaſtically combined.

* Cadenus and Vaneſſa.

There

There is, perhaps, no paſſion ſo improvable by aſſociation as love; it is connected with many ideas that tend to refine, ſoften, and elevate the ſoul, and to increaſe the paſſion under the appearance of increaſing preſent pleaſure. We are not to wonder, therefore, that it has proved ſo copious a means of playing with our feelings in poetical and dramatic compoſitions. To feel and ſympathize with ambition we muſt be particularly circumſtanced, and then our thoughts are generally too ſtrongly bent on the purſuit to attend to imagination. Ambition is an active, love a ſedentary paſſion.

Some concluſions in favour of the practicability of virtue will enſue from the preceding principles. In the firſt place, much of the government of the paſſions will hence appear to be in our own power, by avoiding pernicious aſſociations, and by early care; hence we may learn how to reſtrain the enthuſiaſm of avarice and ambition, by tracing them to their ſource. In our choice of friends and books alſo, we may learn to be cautious to avoid thoſe from which ill habits or prejudices may be derived; we may be inſtructed further to be aware of the effects of cuſtom in acquiring a fondneſs for trifles, and eſpecially for gaming, and other unnatural propenſities; we may learn to direct our affections to proper objects, to aſſociate the pleaſing with the uſeful, or, by force of reaſon and reſolution, to diſentangle thoſe improper combinations which we may have formed. This, indeed, ſeems to be the great uſe of reaſon and ſcience, viz. to enable us to purſue and unravel the chain of aſſociations, which our affections may have extended, and to diſcern plainly the *littleneſs* of the common and ruling paſſions of mankind.

CHAP. XIV.

OF REASONING*.

Common Senſe; what.—Defective Reaſoning.—Analogical Reaſoning.—Wrong Data.—Pleaſures of Reaſoning.

REASONING may be defined a chain of judgments, following and depending upon one another, by which ſome general concluſion is attempted†,

The deſign of this chapter will principally be to exhibit ſome detached obſervations, ſuch as may ſupply us with a few cautions againſt the moſt common defects in reaſoning, which will be found in general to depend upon a falſe or unnatural aſſociation of ideas. Thus, repeated obſervation of the proper and uſual relations of things produces a preſumption in the mind, that thoſe which are accidental may be equally well founded; and this appears to be the undoubted cauſe of what is called prejudice.

When the train of ideas flows in its natural courſe, that is, according to the true relations of things, then

* With this chapter the third diviſion, or the miſcellaneous part of this book, commences.

† "Senſe and memory are but knowledge of fact, which is a thing paſt and irrevocable; ſcience is the knowledge of conſequences, and the dependence of one fact upon another, by which, out of what we can preſently do, we know how to do ſomething elſe when we will, or the like another time."—Hobbes Leviath. pt. 1. c. 5.

the opinions and conclusions formed will be just. When it is warped out of its natural course by an accidental association, then such opinion, and every action founded upon it, will be false. Thus, while men annex the idea of honour to patriotism, and that disinterested benevolence which prompts a generous spirit to disregard its own advantage in contending for the safety and welfare of others, they reason according to the common order of nature; but if they by any means narrow the sentiment, and can persuade themselves that it is lawful to destroy or injure some for the sake of others, that false notion of honour is generated, which produces war, devastation, and conquest; if to this they annex the idea of insult, as heightening the honour, and add the idea of cruelty to insult, which the warmth of passion may readily lead them to do, or if it should seem a mark of courage to taste the blood of their enemies, they will think it honourable and right to torture, and perhaps to devour them *. That the universe must have a first cause, that a first cause must be self-existent, that a self-existent being must be eternal, that an eternal and self-existent being must be without imperfection, is a chain of reasoning that leads directly to a knowledge of the wisdom and goodness of our Creator, and ought to inspire us with a desire

* "The beginnings of this corruption may be noted in many occurrences, as when an ambitious man, by the fame of his high attempts, a conqueror or a pirate by his boasted enterprizes, raises in another person an esteem and admiration of that immoral and inhuman character, which deserves abhorrence; 'tis then that the hearer becomes corrupt, when he secretly approves the ill he hears; but on the other side, the man who loves and esteems another, as believing him to have that virtue which he has not, but only counterfeits, is not on this account either vicious or corrupt."— Shaftsbury's Enquiry con. Virtue, b. 1. p. 2. s. 3.

of

of imitating his perfections; but if, from personifying the deity *, men shall once give room to conceive of him as having parts and passions, fancy will soon be sportive on the occasion, and the amours of Jove, and the contentions of the Gods, will become a part of the popular religion. What effect such an error must have on morals is obvious. While surrounded with the bounties and mercies of God, we can never altogether lose the idea of his goodness; if, therefore, to the admiration of the deity, the idea of vice or passion should be annexed, these will lose their deformity, and, however contrary to men's better judgments, such vices may even be held in esteem.

Some respectable writers have endeavoured to make a distinction between reason and what they call common-sense. But, perhaps, all that can be fairly asserted is, that some propositions are more nearly connected with sensible impressions than others, and therefore the train of reasoning is less liable to be diverted into a wrong conclusion, than in abstruse speculations, or those which are far removed from being objects of the senses, where the variety of associations affords a greater scope for error. Thus, "that things equal to one and the same thing are equal to one another;" "that nothing material exists without a cause;" "that therefore, this world has a first cause," and such like,

* Because we can have no distinct ideas, but those combinations which we form of sensible impressions, mankind have in all ages been inclined to personify the invisible first cause of the universe, for the sake of having a distinct idea of him; and as the human form is the most familiar to them, as well as the most honourable, they have generally adopted that. This deception of our nature persevered in, has led them to assign him appetites, passions, &c. the same with the evil principle, and hence the origin of all superstition.—See Essays Historical and Moral.

are propoſitions immediately connected with experience, and therefore admitted without heſitation. That the angles of a triangle are equal to two right angles, is a truth no leſs certain, but cannot be demonſtrated without a conſiderable train of reaſoning. This remark will apply to many diſputes in morals, theology, &c. Thoſe facts which lie neareſt the teſtimony of our ſenſes will meet the eaſieſt reception.

I have called reaſoning the arithmetic of words, in which falſe concluſions may be drawn, either from wrong data, or from an error in the operation. It will follow, that the concluſions of our reaſon, and our immediate feelings, may be ſometimes at variance. It is common to ſay, "I feel confuted, but not convinced;" that is, on ſome former occaſions, by common experience, you have united certain conſequences with certain things or actions; and another perſon, by a certain chain of reaſoning, ſome one ſtep of which may be falſe, but to which you have not attended cloſely enough to detect the error, now exhibits a different concluſion. Paſſion itſelf will often play the part of the ſophiſt, and determine men to act in contradiction to a concluſion founded on common experience*: "Video meliora, proboque, deteriora ſequor."

Errors moſt frequently happen in what is called reaſoning by analogy. Analogical reaſoning is grounded on the reſembling parts of complex ideas, and as long

* As bodily pain is an unuſual ſtate, and can never be entirely forgotten, however engaged the perſon may be, but will of courſe awaken the attention frequently to ſuch objects and ideas as are connected with it; ſo a paſſion, being an unuſual ſtate of mind, ſomething analogous to the ſuffering of the body, will frequently awake it from other purſuits, and turn it to thoſe ideas which are connected with it.

as we are careful to note the proportions of those resembling parts, and how far in each of the compared ideas they may be connected with, and influenced by others, it will generally prove a safe method of reasoning; but as the associations are not near so strong in this relation, as in that of cause and effect, as the relation is more complex and more removed from common experience, this mode of reasoning will more frequently deceive us. Thus, " if we argue from the use and action of the stomach in one animal to those in another, supposed to be unknown, there will be a probable hazard of being mistaken, proportional in general to the known difference of the two animals, as well as a probable evidence for the truth of part, at least, of what is advanced, proportional to the general resemblance of the two animals; but if, on examination, the stomach, way of feeding, &c. of the second animal should be found, to sense, the same as in the first, the analogy might be considered as an induction, properly so called, at least as approaching to it*."

Reasoning may likewise be defective and false, from accepting an axiom or conclusion drawn from a former judgment as an intuitive principle, or from an imperfect or partial view of the subject, and from what has been said of custom, it is evident that it may have a great influence over our reasoning. Since ideas by re-

* " It is often in our power to obtain an analogy where we cannot have an induction, in which case reasoning from analogy ought to be admitted; however, with all that uncertainty which properly belongs to it."—Hartley on Man, Prop. 39.

" The analogous natures of all the things about us are a great assistance in decyphering their properties, powers, laws, &c. inasmuch as what is minute or obscure in one may be explained and illustrated by the analogous particular in another, where it is large and clear; and thus all things become comments on each other in an endless reciprocation."—Hartley, Prop. 39.

petition become more vivid, and acquire more force if associated with pleasurable sensations, it follows that it will require much force to overcome this slavery, which the mind fabricates for itself, and that no less than demonstration from an actual appeal to the senses, or from acknowledged principles, will be able to undo it †.

The pleasures of successful reasoning result, 1st, From the action it gives to the mind; 2dly, From the pleasure connected with the end we propose to ourselves from the investigation. In fact there is a pleasure attendant on the accomplishment of every end or design; for as all the first actions of men have a tendency to the gratification of their appetites, and the fulfilling of this design has ever been attended with agreeable sensations, we expect the same on the accomplishment of every intention or action whatever.

† The following may be taken as a general abstract of the most common fallacies which occur in reasoning.

1st. Taking an accidental conjunction of things for a necessary connection; as when from an *accident* we infer a property; when from an example we infer a rule; when from a single act we infer a habit. 2d, Taking that absolutely, which ought to be taken comparatively, or with certain limitations. The construction of language often leads into this fallacy; for in all languages it is common to use absolute or general terms, to signify things which carry in them some secret comparison; or to use unlimited terms to signify what, from its nature, must be limited. 3d, Taking for the cause an *occasion* or *concomitant*. 4th, Begging the question *i. e.* assuming the thing to be proved from the premises. 5th, Mistaking the question. When the conclusion of the syllogism is not the thing that ought to be proved, but something else that is mistaken for it. 6th, When the consequence is mistaken; as if, because all Africans are black, it was taken for granted that all blacks were Africans. 7th, Propositions that are complex, often imply two affirmations, whereof one may be true and the other false; as when it is affirmed, *that such a man has left off playing the fool*—if granted it implies that he has played the fool; if denied, seems to imply, that he does so still.

CHAP. XV.

OF THE FINE ARTS.

Music.—Painting.—Poetry.—Wit.

THE chief sources of pleasure in works of art are, 1st, As far as they contain of the primary constituents of beauty. 2d, Resemblance to things which have pleased in our former life. 3d, Utility. 4th, A sense of the ingenuity required. 5th, Fashion, and a deference to the opinion of others.

Music is agreeable, I might almost say entirely, from the combinations of notes naturally agreeable, or from the proper contrast of these notes; from the variety of emotions produced by these combinations, and from these emotions being judiciously contrasted; and I suppose good composers, whether acquainted or not with this general theory, have recourse to these principles *. Very little of the pleasure of music has any relation to the gratification of appetite, or is at all associated pleasure. Indeed, the remembrance of certain sounds which may have been combined with other ideas of actions or passions, may, by recollection, be productive of associated pleasure, as well as of various emotions †.

* It is worth consideration, whether the agreeable sounds are not the most frequent, and the dissonant the most uncommon, &c. Those sounds and combinations of sounds which resemble the human voice may, perhaps, by association, give rise to the agreeable of music.

† See Dryden's Ode to St. Cecilia.

Painting derives its chief power of pleasing from the happy imitation of objects that have the power of renewing agreeable sensations; yet here much depends on a judicious use and disposition of the primary elements of beauty: lively colours, proper contrasts, the waving line, are always attended to by excellent painters.

Poetry depends little on the primary ingredients of beauty or pleasure, except in what respects the measure of the verse; and one reason for the pleasure of verse I apprehend to be, the agitation occasioned by renewing ideas and sensations, such being the return of sounds, and this especially when properly enlivened with new ones. Perhaps in descriptive poetry the beauties of contrast may be proper to be attended to; thus it steals some of the beauties of both music and painting; but its chief power over the mind is derived from the associated or factitious sense of pleasure, and from a representation of those objects which, by interesting the passions, produce mental emotion. It is remarked, that imperfect characters are most agreeable in poetry; the reasons I suspect to be these. 1st, Because we find in them a picture of ourselves, and often a sort of excuse for our own frailties. 2dly, Because there is more of the sublime in occasional sallies of vice or passion, than in uniform goodness. 3dly, Because of the contrast between the good and bad parts of the character, the latter really setting off and making more conspicuous the former. I have already mentioned the pleasure of figurative language, resulting from the variety of thought and emotion introduced by the two trains of ideas *; and it is remarkable that, " when figurative

* " Though the metaphor began in poverty (of language) it did

rative words have recurred ſo often as to excite the ſecondary idea inſtantaneouſly, they loſe their peculiar beauty and force *." It is a miſtake, when critics tell us that florid language is not the language of paſſion; experience amply convinces us of the contrary. The truth is, that ſorrow, reſentment, or any violent paſſion (provided the reaſon is not injured) renders the mind more active, and though it never wanders very far from the ſubject, yet it indulges itſelf in many excurſions, ſtill recurring to its origin.

The ſame qualities, but differing in the degree, are required to form both the poet and the orator; in the latter more ſolidity is wanted. An oration, if compoſed like a poem, would be too florid and deſultory. Quinctilian points out the firſt qualification of an orator to be a good man: this, above every other circumſtance, prediſpoſes the hearers in his favour; beſides, it ſuppoſes him more intimately acquainted with the nature of virtue, and abler to ſpeak in its favour with force and energy.

Wit is the calling together two or more differing ideas by ſome nice and unexpected connection, relation, or correſpondence. The pleaſure of wit conſiſts, 1ſt, In ſurpriſe. 2dly, In the agitation produced by variety, and the different trains of thought. 3dly,

did not end there. When the analogy was juſt (and this often happened) there was ſomething peculiarly pleaſing in what was both new and yet familiar, ſo that the metaphor was then cultivated, not out of neceſſity, but for ornament. 'Tis thus that cloaths were firſt aſſumed to defend us againſt the cold, but came afterwards to be worn for diſtinction and decoration."—Harris's Philological Enquiries.

* Hartley, prop. 46.

In

In ſeveral agreeable ideas, which muſt be of courſe recalled*.

* "The ſame kind of contraſts and coincidences, which in low and comic things would be wit and humour, become the brilliant paſſages that affect and ſtrike us moſt in grave poetry." —Hartley.

"Omnia noſtra, dum naſcuntur, placent."—Quint. l. x. c. 3. The action of the mind in forming any work is pleaſing; and even if it is ſuch as carried with it a good deal of labour and conſequently ſome pain, we feel joy on perfecting it.

CHAP. XVI.

OF MORALS.

Use of the Doctrine of Association in Morals.—Two Theories of Morals.—A Moral Sense.—The Arguments against a Moral Sense.—A strong Argument for Divine Revelation.

THE principal use of the doctrine of association, when applied to morals, will be, to induce us to reflect how little of our happiness depends immediately on sensual enjoyments, and how we may enlarge and improve our lot of pleasure, by cultivating those intellectual delights, which neither injure our health nor reputation, and yet are replete with the most exquisite delight.

Another point which this doctrine tends to establish, may, I think, be made of advantage to mankind, viz. that what is naturally good or ill in a temper depends on a few principles, which may be in a great measure counteracted by other ideas and associations sufficiently grounded and enforced. Hence it follows, that we may be in a considerable degree the framers of our own dispositions *; and inasmuch as reason must be our guide in morals, civilization is eminently of use

* Disposition is a general term, implying the bent or general direction of the mind. Thus we say, an angry disposition, &c. or, *testiness* is a disposition to be angry.

to

to ſociety, the great advantage of which ſeems to conſiſt in the increaſe of intellectual pleaſure *.

Among moral writers, two theories, materially different, have long exiſted, reſpecting the nature of our ſentiments of virtue and vice. Our love of the former, and deteſtation of the latter, is by the one party aſſerted to be an inſtinctive principle, independent of knowledge, or of former ideas admitted by the five ſenſes; and by the other, to be nothing more than the reſult of experience or information.

For the firſt of theſe hypotheſes, the arguments are many and forcible. 1ſt, There are, it is obſerved, in all languages, words equivalent to duty and intereſt, which men have conſtantly diſtinguiſhed in their ſignification. 2d, The emotions which are produced by the contemplation of what is right and wrong in conduct, are different from thoſe which are produced by a calm regard to our own happineſs; ſo much ſo, that we judge extremely differently of the conduct of other men, and of ourſelves in the ſame circumſtances. 3d, The ſentiment of approbation or diſguſt which is excited by any action is inſtantaneous, and not the effect

* "It is of the utmoſt conſequence to morality and religion, that the affections and paſſions ſhould be analyzed into their ſimple compounding parts, by tracing the ſteps of the aſſociations which concur to form them; for thus we may learn how to cheriſh and improve good ones, check and root out ſuch as are miſchievous and immoral, and how to ſuit our manner of life, in ſome tolerable meaſure, to our intellectual and religious wants." &c. "The world is, indeed, ſufficiently ſtocked with general precepts for this purpoſe; and whoever will follow theſe faithfully, may expect good ſucceſs. However, the doctrine of aſſociation, when traced up to the firſt rudiments of underſtanding and affection, unfolds ſuch a ſcene as cannot fail both to inſtruct and alarm all ſuch as have any degree of intereſted concern for themſelves, or of a benevolent one for others."—Hartley.

of

of reaſoning or deduction; theſe ſentiments are alſo excited even in children, long before they have learned to make uſe of their reaſon, or to form in their own minds any regular judgment concerning the good or evil conſequences of action. 4thly, The general agreement of all nations (only making ſome allowances for local circumſtances) with reſpect to moral excellence or moral turpitude, is alſo cited as a proof that theſe ſentiments muſt proceed from ſome general and inſtinctive principle. 5thly, It is aſked, what is meant by the term conſcience, and that uneaſy ſenſation which accompanies guilt, if there is nothing conſtitutionally in man to direct him in the purſuit of good and the abhorrence of evil?

In oppoſition to this doctrine it is urged, with ſome plauſibility, 1ſt, That the moral ſenſe improves * with years and knowledge. What moral ideas, it is ſaid, had the ſavage girl caught in the woods of Champaine? What had the young man of Chartres, who recovered his hearing at the age of twenty-four †? Uninformed perſons of every nation have not an exquiſite moral ſenſe,

* This argument is, however, not deciſive, ſince any one of our ſenſes, and even our bodily powers, may be improved by practice and inſtruction.

† A young man of the town of Chartres, between the age of twenty-three and twenty-four, the ſon of a tradeſman, and deaf and dumb from his birth, began to ſpeak of a ſudden, to the aſtoniſhment of the whole town. He gave them to underſtand, that, about three or four months before, he had heard the ſound of the bells, and was greatly ſurpriſed at this new and unknown ſenſation. After ſome time a kind of water iſſued from his left ear, and he then heard perfectly well with them both. During theſe three months he was ſedulouſly employed in liſtening, without ſaying a word, and accuſtoming himſelf to ſpeak ſoftly, ſo as not to be heard, the words pronounced by others. He laboured hard alſo

ſenſe, and infants very little of it. 2dly, We feel, and reſent as ſtrongly, any thing which contradicts the religion or cuſtoms of our country as thoſe vices which are generally diſallowed, and this can by no means be ſuſpected to be innate. 3dly, What is called virtue is generally profitable. Nor does it at all derogate from the honour of virtue, that it is founded on the immutable principles of truth: a much more honourable extraction than blind inſtinct. 4thly, The neceſſity which all religious perſons admit of a divine revelation to teach us our duty, and the great imperfection of all the ſyſtems of morals that have proceeded from the Heathen ſages *, ſeem greatly to militate againſt the hypotheſis of an innate moral principle.

alſo in perfecting himſelf in the pronunciation, and in the ideas attached to every ſound. At length having ſuppoſed himſelf qualified to break ſilence, he declared that he could now ſpeak, though as yet but imperfectly. Soon after, ſome able divines queſtioned him concerning his ideas of his paſt ſtate; and principally with reſpect to God, his ſoul, the moral beauty of virtue, and deformity of vice. The young man, however, had not driven his ſolitary ſpeculations into that channel. He had gone to maſs, indeed, with his parents; had learned to ſign himſelf with the croſs, to kneel down, and to aſſume all the grimaces of a man in the act of devotion. But he did all this without any manner of knowledge of the intention or the cauſe; he ſaw others do the like, and that was enough for him. He knew nothing of death, nor did it even ever enter his mind. He led a life of pure animal inſtinct; and though entirely taken up with ſenſible objects, and ſuch as were preſent, he did not ſeem to have made ſuch reflections even on theſe as might have been expected; though he did not want underſtanding.——Mem. Acad. Science 1703, p. 18, cited by Buffon.

* See Eſſays Hiſtorical and Moral. Eſſay, Principles of Morals.

There

There are ſome points, it is added, in which all men agree; becauſe there are ſome deductions, which all men endued with ſenſes nearly alike, cannot fail to draw. There are ſome ideas which will be aſſociated in every mind that reflects. Of this nature are the common opinions of virtue and vice. Every being ſenſible of pleaſure and pain muſt alſo be ſenſible of love and hatred. Very little experience will convince any man that particular actions are attended with ill effects, and others in like manner with good ones. No matter whether to ourſelves or others, we have the idea good and bad annexed to the actions, before we have the idea of the perſons to whom they relate; we have them from our own experience, or ſomething adequate: we love the one and hate the other, we love whatever promotes the one, and the contrary.

We very early come to have a ſenſe of injuſtice, ſince whatever diſappoints the appetites, or is productive of preſent pain, generates reſentment in an infant. Theſe ideas are regulated by reaſoning and education, and men in time learn to diſtinguiſh between a misfortune merited, or which they have brought upon themſelves, and one which is brought upon them by others; they learn too to diſtinguiſh between chance and deſign, and hence our hatred to injuſtice, &c.

The quick ſenſe of honour and ſhame, it is further alledged, can be no argument in favour of inſtinctive morality, for we are much more aſhamed of natural defects; there are few men that would not rather be called knaves than fools.

The reaſon men are aſhamed of ſenſual enjoyments, is the loathing and diſguſt that follow exceſs in them; there is no exceſs, no diſguſt, no ſatiety in the

pleasures of imagination, we can therefore bear to reflect upon them.

Should we reject on these grounds the doctrine of an instinctive moral sense, the argument will, in my opinion, be extremely cogent in favour of the necessity of a divine revelation to confirm men in the right path of reason, and counteract those errors which false associations may produce.

CHAP. XVII.

OF GENIUS.

General Obſervations on what conſtitutes Genius.—Of the Varieties in Genius.—Genius oppoſed to Dulneſs.—Different Caſt of Genius.

SOME men, it is well known, feel more acutely impreſſions on their ſenſes than others, and theſe impreſſions probably remain longer vivid on ſome than on others. It ſeems not unlikely, therefore, that this faculty of feeling more acutely, and the impreſſions on the ſenſes dwelling longer vivid in ſome men than in others, enables them to form more extenſive combinations, and connecting together more effectually their ideas, may conſtitute what is called genius, in oppoſition to ſtupidity or dulneſs *. Such a faculty will enable men to acquire knowledge more eaſily, by more readily admitting perceptions; to retain it better by the frequent repetitions, which ſo many aſſociated ideas muſt produce; and to expreſs it more readily from the connexion of ideas, which will recal each other in a more complete and regular ſeries. Men of this de-

* Genius on theſe principles ſeems to be an active power of quickly combining ſimple ideas, or of diſcovering their combinations. Dulneſs to be no more than a ſluggiſhneſs of mind, which is incapable of following the combinations of notes in a fine piece of muſic, or of the colours in a good landſcape, though the ſimple ideas may be obvious enough.

ſcription will have more objects of pleaſure and of beauty than ordinary minds. Relations which would have eſcaped the majority of mankind, will be impreſſed on their ſenſes, and combinations will be formed of which others could have no conception. Their minds branched out, in a manner, to more objects, will in fact have more ſources of pain and pleaſure; only that as the portion of pleaſure is greater than that of pain in the world, their pleaſures will be proportionably more numerous.

But there are other differences ſubſiſting among men of apparently equal genius, which ſeem difficult to be accounted for. One man ſhall excel in an art for which another poſſeſſes no qualification, who yet is at the ſummit of excellence in ſome other. That the paſſions muſt have an effect in forming our diſpoſition * and caſt of thinking, cannot well be diſputed; and the paſſions being no more than modifications of the appetites, on them muſt in ſome meaſure ultimately depend the turn of mind in particular perſons.

I can eaſily conceive that one ſenſe may be ſo perfectly and delicately organized, as to be more ſuſceptible, to diſtinguiſh more nicely, and to preſent the ideas of that ſenſe more perfect than the other ſenſes; and this is probably the caſe with thoſe who poſſeſs a very fine muſical ear without any acuteneſs of under-

* How far the natural frame of the body or the violence of appetite may influence the mind, is not eaſy to define. A delicate habit, unable to bear the extremes of cold and heat, or any other inconvenience, may diſpoſe the perſon to be cautious, ſuſpicious, fretful. The ſame may in the end render him avaricious. On the other hand, there are paſſions which almoſt entirely depend on early aſſociations of ideas.

ſtanding.

ſtanding. But in general this delicacy is extended to all the mental organs, or, to ſpeak more properly, perhaps, to the mind itſelf. Hence a genius for all the fine arts commonly exiſts in the ſame perſon, and if they have applied only to one, we may reaſonably conclude an early bent to have determined the preference.

It is allowed that a quick perception, a proper degree of retention, and a facility in recalling its ideas, are as eſſential to a ſound judgment, as to a fine imagination *; the great difference ſeems to be, that the one ſelects and dwells upon ſuch ideas as are neceſſary to its immediate purpoſe in diſcovering truth; the other ſelects only ſuch as give pleaſure, and does not dwell long upon any. It is probable, therefore, that this is chiefly a difference in temper and diſpoſition. Acuteneſs of feeling is certainly ever connected with fine parts, being in fact no other than quick perception; but it is certain, that among men of equally acute feelings, ſome are leſs violent and ſanguine than others.

* The philoſophic genius, according to Dr. Gerard, differs from a genius for the arts, in this, that the former is chiefly employed upon the relations of effects and cauſes, and the latter is attracted by the relation of reſemblance, conſequently the one dwells on a few principles, the other purſues every light and fanciful aſſociation.

"The philoſopher deſcribes minutely all the appearances of his object; his deſign requires it; every one of them involves ſome truth; inattention to any one of them may prevent the diſcovery of truth, or occaſion error; thoſe of them which ſeem leaſt ſtriking, often lead moſt directly to truth, or lead to the moſt important truths. A poet, on the contrary, would overlook by far the greateſt part of theſe appearances; they are unfit to pleaſe, and for that reaſon attract no ſhare of attention: he fixes on a few that are moſt ſtriking, and labours to ſet theſe in a ſtriking light."—Ger. on Gen. pt. 3. ſ. 1.

I can by no means consent to refer this difference altogether to education, for persons who have had every possible care taken of their temper in early youth, will often, when set at liberty, break out, and become of very unruly dispositions in maturer age; and persons will resemble their parents in temper, who have never seen them:

> "Naturam expellas furcâ, tamen usque recurrit."

This fact we can refer to no one principle in human nature but the passions. Those whose animal appetites are stronger than those of others, will be more sanguine in all their desires, of course will smart more for a disappointment, and, in a word, must be more subject to passion.

The old maxim, "Poeta nascitur," has been accounted a vulgar error, and it is certain much depends upon early habit, and this habit is commonly acquired from the circumstances of youth. But this does not entirely account for the difference of men's pursuits, whose mental powers seem equal, and whose situations are similar. If once it is agreed, however, that a degree of coldness is necessary to certain studies, and that others are more connected with passion, we shall not long be at a loss to account for this seeming paradox in the human mind, upon the principles already established.

There are other causes of diversity in natural genius, such as difference in the degree, &c. One man is possessed of a more retentive memory than another; another man may have a more lively perception, and a little difference in principle will produce a great one in the effects. These persons may seem men of equal talents, and yet the bent of the genius will

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be different in each, and their qualifications different. After all, it is difficult to ſay what may be the effects of cultivation. Many excellent practical muſicians are certainly not men of genius, nor even poſſeſſed, as I have been informed, of a natural genius for their own art. What moſt commonly influences the purſuits and diſpoſitions of men is, I am perſuaded, cuſtom *, early aſſociations, and a predilection for certain occupations generated by ſome agreeable but fortuitous circumſtance. Thus, in relating the life of the poet Cowley, Dr. Johnſon informs us, that, "In the window of his mother's apartment, lay Spencer's Fairy Queen; in which he very early took delight to read, till by feeling the charms of verſe, he became, as he relates, irrecoverably a poet. Such (adds this great moraliſt) are the accidents, which ſometimes remembered, and perhaps ſometimes forgotten, produce that particular deſignation of mind, and propenſity for ſome certain ſcience, which is commonly

* Much of the difference between the ſcientific genius, and the genius for the arts, will depend on early habit. "Perſons (ſays Dr. Hartley) who give themſelves much to mirth, wit, and humour, muſt thereby greatly diſqualify their underſtandings for the ſearch after truth; inaſmuch as by the perpetual hunting after apparent and partial agreements and diſagreements, as in words, and indirect, accidental circumſtances; whilſt the true natures of the things themſelves afford real agreements and diſagreements, that are very different or quite oppoſite, a man muſt by degrees pervert all his notions of things themſelves, and become unable to ſee them as they really are, and as they appear to conſiderate, ſober minded inquirers. He muſt loſe all his aſſociations of the viſible ideas of things, their names, ſymbols, &c. with their uſual practical relations and properties; and get in their ſtead accidental, indirect, and unnatural conjunctions of circumſtances, that are really foreign to each other, or oppoſitions of thoſe that are united."—Hartley, p. 46.

called genius. True genius is a mind of large general powers, accidentally determined to some particular direction. The great painter of the present age, had the first fondness for his art excited by the perusal of Richardson's treatise *."

* Johnson's Lives, vol. 1. p. 4.

CHAP. XVIII.

OF TASTE.

Of Agreement and Disagreement in Taste.—Of a Standard of Taste.

DISAGREEMENT of tafte, if we but attend to the principles explained in the former part of this book *, will be found to arife from particular affociations †; and agreement in tafte from the natural affections common to all mankind. The moft perfect agreement will be between thofe whofe genius, ftudies, and other circumftances moft perfectly accord.

National tafte is influenced by the fame caufes, which influence that of individuals ‡, and a flight affociation will frequently produce the moft fantaftical cuftoms. The tyranny exercifed over the female fex, the jealoufy of the Afiatic nations; and the neglect of their women, fhewn by fome northern barbarians, does not proceed from a coldnefs in the natural temper of the latter, nor from the more lively paffions of the former; the truth is, in the rude ftate of thofe northern people, their

* See ch. xi.

† From affociation, if glaring colours, or any other thing fhould be regarded by the country as a fign of levity or any other ill quality in the wearer; or if any colour or fafhion is ufed by ruftics, or men of a difagreeable profeffion or temper, thefe ideas recur with the fafhion or colour.

‡ Almoft every perception will introduce a different train of ideas in every different perfon, according to the different circumftances with which it may have been moft frequently affociated in each perfon's mind, and confequently often according to their particular occupation or profeffion.

other wants are ſo many, that they cannot attend to the pleaſures of luxury. But the ſouthern nations, by the aid of a fine climate and a fertile ſoil, are more advanced in civilization than thoſe of the north, though not arrived at that point when the mind is enabled, by reaſon and philoſophy, to reſiſt or correct falſe aſſociations. The one party have little notion of pleaſure, the others have miſtaken notions of it. A ſingle movement in the intellectual world influences a train of ideas, and, if wrong, produces a ſeries of miſconduct. It is certainly a conſtituent of female beauty, to have limbs ſmaller and more delicate than thoſe of men; but mankind are ever deſirous of pleaſure and beauty to exceſs; the Chineſe, therefore, endeavour to produce a degree of beauty beyond what nature has eſtabliſhed as perfection, and cramp the feet of their women even to deformity: the ſame motive will ſerve to explain many fantaſtical faſhions which occur to our own obſervation. What induced ſome of the Indians to colour the teeth black, was ſuppoſing it eſſential to men to differ from the brutes in every reſpect, and therefore it was neceſſary not even to have teeth of the ſame colour.

Deviations from nature happen chiefly in a ſtate a few removes from barbariſm. True refinement brings men round to the primitive ſimplicity from which they have been diverging. Whether the theory of a moral ſenſe is admitted or not, it is ſtill highly probable, that there is in all things a certain perfection of which mankind is naturally emulous. The ideal characters, and the golden age of poets, exhibit the original traces of the conſciouſneſs of this perfection, written in the breaſt of every man. It is on this ſtandard of excellence in human nature, that a ſtandard of taſte probably depends. As men approach more or leſs this

point

point of perfection, they are called polite or rustic, civilized or barbarous; and though the point itself has never, perhaps, been attained, nor ever will be attained by any, yet men there will be in every age who approach nearer to it than the great mass of mankind, and in some ages they will abound more than in others; from the number of these we are to form our judgment of the taste of any given period; these, in fact, it is who lead the fashion in thinking; and although there are degrees in this intellectual excellence, yet all men will be admirers and judges of perfection in arts or in morals, in an exact proportion as they approach perfection themselves, provided only they have made themselves perfectly acquainted with the principles of that art of which they presume to judge.

CHAP. XIX.

OF OPINION.

Paradox of the Stoics.—Explanation.—The ſenſible Pleaſures more numerous than the ſenſible Pains.—The ſame with the intellectual Pleaſures and Pains.

IT was a dogma of the ſtoics, that good and evil depend upon opinion—Take away the opinion (ſay they) and the evil is removed *. This paradox is, perhaps, not wholly incapable of explanation. Certain it is, that if we except the ſenſible pleaſures and pains, much of our temporal happineſs and miſery does depend upon opinion; that is, upon an imaginary eſtimation or fear acquired from aſſociations of ideas. What renders a particular walk or apartment agreeable after being for ſome time habituated to it? but that the idea of the place becomes entwined and connected with the pleaſures enjoyed in it. What gives value to the lover's keep-ſake or the miſer's gold? not that either are of any uſe to them, but the one is aſſociated with the pleaſure of ſympathy, the other with that of convenience †. The moraliſts, therefore, who aſſert that we

* See M. Anton. Med. Arrian Paſſim.

† Darkneſs and obſcurity are the only means by which the eye can be materially deceived in judging of bodies.—The fancies, therefore, of apparitions, whenever they aroſe, moſt probably took their riſe from ſome miſconception of this kind; and, indeed, the little probability there is that men could be deceived in the open day, made obſcurity be always choſen as the proper ſcene for terrors of this kind. Nay, the fear and caution which people muſt have in the dark on account of the danger there is of falling or injuring themſelves; the opportunity it affords for ambuſcades, &c. and

we may be, in a great measure, the fashioners of our own happiness, are, perhaps, not materially mistaken. The sensible pleasures are more numerous than the sensible pains; but the greater part of our happiness is intellectual, or formed by the imagination. If, therefore, we can become such masters in reasoning, as to analyze and decompose those passions which the imagination forms, the fairy fabric is dissolved, and our uneasiness is removed. Nor need we be prevented from uniting together agreeable aggregates of ideas, in which work nature will assist, and for the reason above intimated, viz. because the sensible pleasures are more numerous than the sensible pains, and because the mind is only active in pursuit of pleasure.

and being the common time for committing outrages and murders, must increase this apprehension. Besides it deprives us in some measure of society, and cuts off many pleasing trains of ideas which objects in the light introduce. After all, probably so much of our happiness depends on the action of our senses, that the deprivation of any one of them is attended with proportionable uneasiness. Much use has been made of this principle in the gloomy construction of religious buildings, &c. superstition being the common offspring of fear.

CHAP. XX.

OF THE FREE AGENCY OF MAN.

Predeſtination, or fatal Neceſſity, not connected with the Doctrine of the Aſſociation of Ideas.—Inconſiſtency of the Fataliſts.—Motive and Action in Morals totally different from Cauſe and Effect in Phyſics.—The Onus Probandi in this Queſtion lies on the Fataliſts.—Queſtion concerning the Influence of Motives.—Argument of the Fataliſts from the Divine Preſcience.—Abſurd and horrible Conſequences reſulting from the Doctrine of Fatality.--Modeſty and Humility recommended in philoſophical Studies.—Thoſe Sciences to be preferred which are moſt connected with practical Utility.

THAT the doctrine of the aſſociation of ideas ſhould, in the mind of any viſionary writer, have ever been connected with the fatal neceſſity of human actions, is, I confeſs, to me a matter of ſurpriſe. Miſerable, indeed, muſt be the ſtate of man, if he was endued with no power of regulating or directing the train of his ideas; if they muſt flow for ever in one neceſſary, unbroken channel, or if external objects alone were to dictate to us what to think. It is obvious, that if this was the caſe, there could be no variety, and ſcarcely any change in the purſuits of men: the thoughts muſt flow from each other in one uninterrupted ſeries, and man could not be an accountable, and ſcarcely a rational creature.

It is, however, plain, that we have a power of interrupting the train of thought, of dwelling more intenſely upon particular ideas, and even of occaſionally diverting our reflections and contemplations

into new channels; and this power alone is ſufficient, in my opinion, to conſtitute man a free agent *. Indeed thoſe authors, who contend moſt for the doctrine of a fatal neceſſity, are among the firſt to recommend an application to ſtudy, and the cultivation of the mind; whereas, if the mind is endued with no ſpontaneous energy whatever, no ſelf directing agency, ſurely ſuch a recommendation is inconſiſtent and abſurd †.

On any queſtion of ſerious importance, analogical reaſoning ſhould be admitted with the utmoſt caution; and yet a ſenſeleſs and puerile analogy has been called in to the aid of an argument, which cannot be ſupported by poſitive proof. Motive and action in morals, have been compared to cauſe and effect in

* It is impoſſible to obſerve, without a ſmile, men boaſting of being the diſciples of Mr. Locke, who have apparently never read a page of his writings, or, if they have looked into them, have evidently miſunderſtood them. With how much juſtice this *real* philoſopher is repreſented as a favourer of the abſurdities of the fataliſts, will appear from the following paſſage: "This at leaſt (ſays Mr. Locke) I think evident, that we find in ourſelves a power to begin or forbear, continue or end ſeveral actions of our minds, and motions of our bodies, barely by a thought or preference of the mind ordering, or, as it were, commanding the doing or not doing ſuch or ſuch a particular action. This power which the mind has thus to order the conſideration of any idea, or the forbearing to conſider it, or to prefer the motion of any part of the body to its reſt, and *vice verſa*, in any particular inſtance, is what we call the will."—Locke's Eſſay, B. ii. c. 21.

† If there is no degree of freedom or ſpontaneity in human actions, what is meant by the words deliberation, prudence, and judgment? If the opinion of the fataliſts is true, our interference in any matter or action is ſuperfluous; and yet who is there that does not perceive, that the courſe of a dangerous diſeaſe may be impeded by the calling in of a phyſician? a matter which was entirely within the choice of the patient himſelf.

phyſics.

physics *. That some motive in the mind precedes every human action is certain, and thus far the analogy is just; but the motive may as well be in the will itself, as the mere result of any external cause. If, indeed, the analogy was true in all its parts, a human being would be altogether as subject to the laws of inert matter as a block of marble or of wood. Whatever is subject to an absolute necessity, can never be the incipient cause, or the beginner of motion or action of any kind; it must be altogether under the command and direction of external objects; it must be altogether inert or passive, having no principle of action in itself. On this account, as I before intimated, there would be much more uniformity in the actions of men, if they were subject to a *fatal* influence, then there appears to be; there would be no difficulty in deciding what must be their conduct in any given circumstances.

A freedom of deliberating, chusing, and determining upon things, is what every man feels in himself †. It

* The arguments by which the atheists have attempted to prove this analogy, are the most absurd and puerile that can well be imagined. "Every effect," say they, "must proceed from some cause, and this cause must be dependent on another." The direct conclusion from this is "that there is no where any origin or beginning of motion, but every thing is necessarily produced by an eternal chain of causes and effects, without any independent origin." Such reasoning as this exactly resembles that of the Indian, who supposes the earth to rest on a crocodile, the crocodile on an elephant—but what does the elephant rest on? In fact, to compare the operations of the mind to any of the qualities of matter, is to compare, as Dr. Clarke observes, a square to the colour of blue, or a triangle to a sound. It is like the blind man, who being asked what idea he had of *scarlet*, said, he fancied it must be something like the sound of a drum.

† "As it is in the motions of the body, so it is in the thoughts of our minds; where any one is such, that we have power to take

is the dictate of nature and common sense; one of the first perceptions we have of the operations of our own minds. It does not lie with us, therefore, to prove, that the human mind is free; but it lies with the opponents of liberty to *prove*, that *it is not free*; and this ought to be done upon direct, positive, experimental evidence, and not upon fanciful analogies or conjecture.

The only argument which the fatalists have ever been able to adduce, which at all bears upon the point, is this—that men act from motives, and these motives are dependent upon situation and external circumstances. This, then, is really the point at issue between the fatalists, and the advocates for the free agency of man. The former suppose the influence of motives from external causes to be absolute and unlimited; the latter allow the influence of the motives to a certain extent, but they deny that it is absolute and unlimited.

In the present state of human knowledge, it is, indeed, a species of dogmatism not to be endured, to pretend precisely to ascertain how far the influence of external motives extends over the mind of man. That external causes should have a certain weight and influence with us, is certainly consistent with the wisdom of Divine Providence, and consistent with that order and regularity which he has every where established. If men were to act entirely independent of all influence from external causes and circumstances, the world would be an entire scene of confusion and disorder; if, on the contrary, they were endued with no power of choice or deliberation, the whole would be an inanimate uniform mass, subject to certain and definite laws, as much as

it up, or lay it by, according to the preference of the mind, there we are at liberty."—Locke's Essay, B. ii. c. 21.

inert matter. In this, therefore, the ſame happy medium appears to be eſtabliſhed as in other inſtances. Man, from his natural relation to external things; from that wonderful connection which exiſts between the body and the mind, is ſubject to a certain influence from ſituation and circumſtances; but there is ſtill in his own mind a power of reflecting, deliberating, and deciding upon his motives and conduct.

Another argument in favour of fatality is deduced from the preſcience of the Deity. "If God foreknows all things (it is alleged) then every event muſt be predetermined." But this argument reſts upon the ſame preſumptuous foundation as the preceding, which would poſitively determine the preciſe degree of *influence* that external cauſes muſt have upon the mind of man. Dogmatiſm certainly never was the road to truth, and is utterly inconſiſtent with that modeſty and humility, which is the very characteriſtic of a real philoſopher. The preſcience of the Deity! Who will dare to ſay that he is able to define it? Who will dare to allege that he underſtands every particular circumſtance and attribute of the Divine exiſtence? To ſay that God *cannot* exerciſe his own powers in that way which is moſt agreeable to the ends that infinite wiſdom propoſes, and infinite goodneſs would dictate, is, to define and limit omnipotence! and to affirm that God cannot conſtitute man a free agent, *cannot* in this inſtance diſpenſe with his own preſcience, is to ſay, that God is not omnipotent. This was long my own opinion; and I was happy to find it confirmed by the excellent and judicious Dr. Henry More, whoſe ſentiments on this ſubject were pointed out to me by a friend. "It is true (ſays he) we cannot otherwiſe think of God's *foreknowledge*, but as being every way clear and perfect, and without poſſibility of error, as to thoſe objects

about which he judges or pronounces. And surely he does always judge and determine of things according as they are; that is to say, of a contingent thing, as it is contingent; and of a necessary thing as it is necessary. Whence it comes to pass, that those things which are contingent and proceed from a free principle of acting, are allowed to be seen by God's consent.

"But, not to confine God's *omniscience* within narrower, nor ascribe to it wider bounds than we do to his *omnipotence*, which all suppose to be an ability to do whatever implies not a contradiction; let us dispatch the difficulty in a few words, by saying, that the *foreknowledge of contingent effects*, which proceed from a *free principle of acting*, does either imply a contradiction, or it does not. If it does imply a contradiction, then such effects are not the object of God's *omniscience*, nor determined by it, nor rightly supposed to be determined at all. But if it does not imply a contradiction, then we actually confess, that *divine prescience*, and *human freewill*, are not inconsistent, but that they may stand together."

The most decisive argument, however, against the fatalists, is, the extravagant conclusions to which this gloomy and comfortless doctrine leads, and the horrible consequences which are attached to it. If man is a *necessary* agent, he cannot possibly be an accountable being; for how preposterous is the thought, how inconsistent would it be with every principle of justice, to punish any being whatever, or in any degree, for what he could not have avoided? In a theological view, therefore, this doctrine appears to conduct directly to atheism; for we cannot conceive of the Deity in such a manner as to suppose him wantonly cruel or unjust. To say that future punishments are not to be (as the orthodox party conceive) eternal in their duration, does not remove the difficulty; to punish *at all* for

for involuntary offences, is cruelty and injuſtice. The ſyſtem of free agency, on the contrary, is conſiſtent with all the attributes of God, and is highly conſolatory and inſtructive to man. This ſyſtem reſts upon the cleareſt baſis of juſtice. Man is created free; he has good and evil placed before him, with the ſtrongeſt and moſt conciliating motives in the Chriſtian diſpenſation to purſue the one, and to avoid the other. If he perverſely takes the wrong courſe, and proves incorrigibly wicked, every principle of reaſon and equity, ſanctions the juſtice of his puniſhment.—Into the nature of that puniſhment, it is not our preſent buſineſs to inquire. It will doubtleſs be ſuch as to ſatisfy infinite juſtice, yet tempered by the ſweet and ſalutary exerciſe of infinite mercy.

If the divine laws are thus outraged by the prepoſterous hypotheſis of a fatal neceſſity; human laws, I fear, will not ſtand upon a much firmer foundation. To puniſh any criminal for an error which he could not avoid, is certainly not only cruel, but wicked in the extreme; and yet ſuch muſt be the caſe, if the doctrine of the fataliſts is true *.

* In the courſe of a very few years, it will ſcarcely be credited, that a book has been lately publiſhed on this very principle, and the argument of the author is briefly this. Man is a neceſſary agent, he is therefore not an accountable being; his actions are all determined by his ſituation and circumſtances, taking in amongſt theſe his education and the degree of knowledge he has been enabled to acquire. What are called *crimes* therefore are only *miſtakes*, perfectly involuntary on his part, and he therefore (whether he is a thief, a murderer, or a parricide) *ought not to be puniſhed*, but *inſtructed* and reaſoned with. As no criminal ought to be puniſhed, all laws or regulations muſt be perfectly nugatory in ſociety, and even pernicious; marriage is law, and therefore it is pernicious, and ought to be aboliſhed.—It is happy for the cauſe of truth, when ſuch books are publiſhed; for if the ſarcaſtic genius of a Swift could have more effectually burleſqued the doctrine of neceſſity, I am no judge of *irony*.

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On the whole, it is the part of true philosophy to avoid equally the dangerous extremes of an arrogant dogmatism, which professes, like the ignorant opponents of Socrates, to know every thing, and of that perplexing skepticism which would deprive the human understanding of capacity and intelligence. As finite beings, many facts are necessarily placed beyond the reach of our researches. They are neither suited to our faculties, nor our situation in this life; and where we have no basis of fact on which to reason, error will generally be the consequence of our indulging in visionary speculations.

To console us for this deficiency, we may still remark, with satisfaction and gratitude, that if much is concealed, much also is known. There is an immense fund of practical kuowledge perfectly within the grasp of our faculties. There is scarcely any human science, which, to know it well, is not sufficient to employ the most protracted existence of man. It will be more consistent with happiness, as well as with modesty, to acquaint ourselves with these, before we launch into the unfathomable abyss of metaphysical speculation; nor indeed can any thing be more disgusting, than to hear a loquacious disputant, who is unacquainted with the plainest and most useful branches of knowledge, presuming to arraign the appointments of omniscience, to "re-judge his justice;" to annihilate the intellectual, and to confuse and disturb the moral world. Much greater is his merit, much sounder is his judgment, who fabricates the simplest machine, or plans or executes the plainest undertaking that may be practically useful to mankind.

Yet we may innocently amuse our curiosity; we may inncently gratify our thirst of knowledge; we may innocently exercise our faculties. But let us, in the

name of reaſon, exerciſe them on their proper objects; let us ſeek for knowledge where it is really to be found; let our curioſity employ itſelf where fact, experiment, and obſervation, may lead to ſome certain concluſion. The book of nature is open to us; the material world is diſplayed for our inſpection, and for our improvement; the intellectual world is covered with an almoſt impenetrable veil. What God has choſen to reveal of himſelf in the holy ſcriptures, may be eaſily comprehended; what he has choſen for the preſent to keep in reſerve, no mortal efforts will ever be able to develope. The ſimpleſt and moſt unlearned perſon who ſtudies with a pure heart, and an undepraved mind, the ſacred volume, is practically wiſe; the brighteſt underſtanding, the moſt exalted genius, who attempts to go beyond it, becomes inevitably a fool.

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